

(2)

IDA PAPER P-2094

AD-A195 751

PRELIMINARY EXPLORATION OF THE USE OF A
WARFARE SIMULATION MODEL TO EXAMINE
THE MILITARY VALUE OF TRAINING

Seymour J. Deitchman

DTIC
ELECTE
JUL 11 1988
S D

March 1988

Prepared for
Office of the Under Secretary of Defense for Acquisition

DISTRIBUTION STATEMENT A

Approved for public release
Distribution Unlimited



INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311

DEFINITIONS

IDA publishes the following documents to report the results of its work.

Reports

Reports are the most authoritative and most carefully considered products IDA publishes. They normally embody results of major projects which (a) have a direct bearing on decisions affecting major programs, or (b) address issues of significant concern to the Executive Branch, the Congress and/or the public, or (c) address issues that have significant economic implications. IDA Reports are reviewed by outside panels of experts to ensure their high quality and relevance to the problems studied, and they are released by the President of IDA.

Papers

Papers normally address relatively restricted technical or policy issues. They communicate the results of special analyses, interim reports or phases of a task, ad hoc or quick reaction work. Papers are reviewed to ensure that they meet standards similar to those expected of refereed papers in professional journals.

Memorandum Reports

IDA Memorandum Reports are used for the convenience of the sponsors or the analysts to record substantive work done in quick reaction studies and major interactive technical support activities; to make available preliminary and tentative results of analyses or of working group and panel activities; to forward information that is essentially unanalyzed and unevaluated; or to make a record of conferences, meetings, or briefings, or of data developed in the course of an investigation. Review of Memorandum Reports is suited to their content and intended use.

The results of IDA work are also conveyed by briefings and informal memoranda to sponsors and others designated by the sponsors, when appropriate.

The work reported in this document was conducted under contract MDA 903 84 C 0031 for the Department of Defense. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that agency.

This paper has been reviewed by IDA to assure that it meets high standards of thoroughness, objectivity, and sound analytical methodology and that the conclusions stem from the methodology.

Approved for public release; distribution unlimited.

UNCLASSIFIED

ADA 195751

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY N/A			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) IDA Paper P-2094			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION Institute for Defense Analyses		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION DoD-IDA Management Office, OUSD(A)		
6c. ADDRESS (City, State, and Zip Code) 1801 N. Beauregard Street Alexandria, VA 22311			7b. ADDRESS (CITY, STATE, AND ZIP CODE) 1801 N. Beauregard Street Alexandria, VA 22311		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION OUSD(A)/R&AT		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA 903 84 C 0031		
8c. ADDRESS (City, State, and Zip Code) Room 3D129 The Pentagon Washington, DC 20301-3080			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT	PROJECT NO.	TASK NO. T-D2-435
11. TITLE (Include Security Classification) Preliminary Exploration of the Use of a Warfare Simulation Model to Examine the Military Value of Training					
12. PERSONAL AUTHOR(S) Seymour J. Deitchman					
13. TYPE OF REPORT Final		13b. TIME COVERED FROM 1/87 TO 11/87		14. DATE OF REPORT (Year, Month, Day) March 1988	
15. PAGE COUNT 61					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) military value, training, warfare model, TACWAR, unit training		
FIELD	GROUP	SUB-GROUP			
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This paper examines how to assess the military value of unit training in the same quantitative cost and effectiveness terms used to assess investments in other areas such as acquisition of new weapon systems or of more forces of various kinds; it is a preliminary effort. The military value of training in relation to the value of weapons or forces is difficult to quantify, and data that would shed light on it are sparse; a new approach is proposed here. The approach consists, first, of experimenting with a large-scale computer simulation of warfare to find how imputed effects of unit training on unit proficiency affect the outcome of a modeled NATO/WP conventional conflict. Second, the outputs of the model runs are reviewed for reasonableness, and are used to set up a series of questions to elicit military judgments and any available data that would indicate the nature and extent of training necessary to achieve effects such as those that emerged from the "test." The final steps will be to estimate the costs of the levels and kinds of training that emerge, and then to use similar modeling techniques (or existing results) to compare investments in training and in force size or force modernization to achieve equal effects on the outcome of the war. This paper describes the first experiments, the results of the initial model runs, and the next steps to be taken in the investigation, in terms of questions to be answered by military experts, data to be gathered if they are available, and analyses to be performed subsequently.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL Jesse Orlansky			22b. TELEPHONE (Include Area Code) (703) 578-2836		22c. OFFICE SYMBOL

UNCLASSIFIED

IDA PAPER P-2094

**PRELIMINARY EXPLORATION OF THE USE OF A
WARFARE SIMULATION MODEL TO EXAMINE
THE MILITARY VALUE OF TRAINING**

Seymour J. Deitchman



March 1988

Accession For:	
NTIS CRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 84 C 0031
Task T-D2-435

ACKNOWLEDGMENTS

This study was performed for the Office of the Under Secretary of Defense (Acquisition) (Research and Advanced Technology), under Task Order T-D2-435. Technical cognizance for this work was assigned to Earl A. Alluisi, Assistant for Training and Personnel Technology. The interest in and support of this work by Dr. Alluisi is deeply appreciated.

The author is indebted to Mr. Edward Kerlin and Dr. Alan Rolfe for setting up and running the TACWAR model for the work described here and for their help in interpreting the results, to Mr. Stanley Horowitz for his useful critique of early results, and to Dr. Jesse Orlansky for nagging at him to take on this task and for his review of and suggested corrections to this paper. The paper was also reviewed by Mr. D.R. Andrews of the British Aerospace Corporation, and Mr. John Metzko of IDA. The author takes sole responsibility for the manner in which the welcome comments of reviewers were incorporated into the paper.

SUMMARY

This paper describes the first stage of an investigation of how to assess the military value of unit training in the same quantitative cost and effectiveness terms used to assess investments in other areas such as acquisition of new weapon systems or of more forces of various kinds.

The military value of training in relation to the value of weapons or forces is difficult to quantify, and data that would shed light on it are sparse; a new approach is proposed here. The approach consists, first, of experimenting with a large-scale computer simulation of warfare to find how imputed effects of unit training on unit proficiency affect the outcome of a modelled NATO/WP conventional conflict. Second, the outputs of the model runs are reviewed for reasonableness, and are used to set up a series of questions to elicit military judgments and any available data that would indicate the nature and extent of training necessary to achieve effects such as those that emerged from the "test." The final steps will be to estimate the costs of the levels and kinds of training that emerge, and then to use similar modeling techniques (or existing results) to compare investments in training and in force size or force modernization to achieve equal effects on the outcome of the war.

This paper describes the first experiments, the results of the initial model runs, and the next steps to be taken in the investigation, in terms of questions to be answered by military experts, data to be gathered if they are available, and analyses to be performed subsequently.

CONTENTS

Acknowledgments	iii
Summary	v
List of Figures	ix
Abbreviations and Acronyms	xi
I. PURPOSE, BACKGROUND, AND APPROACH	1
A. Purpose	1
B. Background	1
C. Approach	4
D. Organization of the Report	6
II. DESCRIPTION OF THE "EXPERIMENT"	7
A. Cases Examined and Variables Considered	7
B. Measures of Effectiveness	8
III. RESULTS OF THE MODEL RUNS	11
A. Effects of Unit Proficiency on the Outcome of the War	11
1. Overall Results	11
2. Air Combat and Sortie Rates	12
3. Ground Attack by TACAIR	15
4. Ground Combat by Artillery and Tanks	15
B. Effects or Artifacts of the Model	18
1. Separating Kill Effectiveness from Vulnerability	19
2. Switching from Defense to Offense	20
C. Overall Significance of the Model Effects	23
IV. DISCUSSION	27
V. APPLICATION OF RESULTS: NEXT STEPS	31
A. The Impact of Enhanced Unit Training	31
B. Effect of Air-to-Air Combat	32
C. Other Available Data	32
D. Cost of Training	32
E. Relative Cost-Effectiveness Comparisons	32

ANNEX 1-- Description of Initial "Experiment" Parameters	35
APPENDIX-- Detailed Data From Model Runs	A-i

LIST OF FIGURES

1. Average FEBA Movement, Air-to-Air Capability Varied.....	13
2. Average FEBA Movement, Training Varied to Affect Sortie Rate	13
3. Average FEBA Movement with Variation in NATO Air-Ground Attack Capability	16
4. Average FEBA Movement with Variation in NATO Tank Capability Due to Training	17
5. Average FEBA Movement with Variation in NATO Artillery Capability Due to Training	17
6. Effect of Separate Variations in Air Attack Effectiveness and Attack Aircraft Vulnerability	21
7. Effect of Separate Variations in Tank Effectiveness (Enhanced) and Tank Vulnerability (Reduced)	22
8. Enhanced NATO Tank Effectiveness	22
9. Modeling Nonlinearities and "Sampling" Effects on the Results	24

ABBREVIATIONS AND ACRONYMS

ACEVAL	Air Combat Evaluation of two-sided multi-fighter interaction in live tests
AIMVAL	Air Combat Evaluation of missile guidance
FEBA	Forward Edge of the Battle Area
FLOT	Forward Line of Own Troops
NATO	North Atlantic Treaty Organization
SAM	Surface-to-Air Missile
SIMNET	Simulator Networking of tank simulators
TACAIR	Tactical Aviation
TACWAR	A Tactical Warfare computer-based simulation model
WP	Warsaw Pact

I. PURPOSE, BACKGROUND, AND APPROACH

A. PURPOSE

The purpose of this paper is to explore one way of evaluating the military worth of training in the same cost and effectiveness terms as are used in evaluating weapons and forces. The method selected for investigation uses TACWAR, a computer-based simulation model that represents a war between NATO and the Warsaw Pact in the central region of Europe. This approach varies the values for some variables in the model that are assumed to represent the performance of well trained, in contrast to less well trained, military units. The results that are examined are the outcomes of the war, produced by the model, as they might be influenced by the hypothesized differences in training.

B. BACKGROUND

This paper describes an exploratory effort to make quantitative estimates of the military value of training. No one doubts the importance of training and therefore its value in preparing for combat. Large sums are expended by all military Services and by all nations for training in field exercises to improve the readiness status of their units for combat. It is widely recognized, however, that readiness reports, heavily influenced as they are by commanders' judgments about training (as well as by quantitative materiel and supply factors) are heavily subjective in nature. Given the fact that training is virtually a mandatory feature of military readiness, obvious questions are, how much training is needed and how often should it be repeated to maintain a desired level of combat readiness. Since the resources needed to support training are measured objectively by the size of a budget in dollars, it is clearly also desirable to be able to measure the products of such expenditures in objective and quantitative terms. This forms the background and reason for the present effort.

Military training is generally placed in two categories: *individual training* develops the information and skills of individuals that they need to perform the very large variety of military tasks. This training takes place at schools for recruits and schools for special

technical skills (such as operating a radar, truck maintenance, firing artillery, primary flight and navigational training, and the like). *Collective or unit training* develops the ability needed by individuals with particular technical skills to perform together as crews of tanks, aircraft and ships, both in small groups and in large combat units. This training takes place in the operating commands and is intended to develop effective military units at all levels of aggregation. This paper is concerned solely with estimating the military value of unit training.

The apparently simple matter of quantifying the extent of unit training in militarily meaningful terms is far from an easy one. Beyond that, the subject of how training affects unit performance, and how that performance can in turn influence the outcome of a battle or a war, is notoriously difficult to examine quantitatively. The available knowledge about the effect of training on the outcome of battles and wars is the stuff of anecdote and history, but quantitative descriptions of the relationships among the multitudinous variables that affect the outcome are usually shrouded in mystery. One often knows the history of units prior to engagement; their state of armament and supply; their movements, tactics, commanders and the commanders' thinking about the battle; even, perhaps, their morale. Mainly, the data are described in broad terms (e.g., the unit was "well trained," with perhaps even the length of time spent in training). But there is insufficient information to perform scientific analyses relating a set of parameters describing the extent of pre-battle training to the outcome. Indeed, in some of the few attempts at such analysis, it is often found that units with apparently equal training do not perform in the same manner at all, and the variables that affected such differences are so numerous that analysts find it impossible to separate their individual effects.¹ Similarly, there are data from exercises that are run for the purpose of training and testing readiness for combat; such exercises often are "set-piece" in that they tend to be run according to carefully planned scenarios and, in addition, they are very expensive, so that few of them tend to be undertaken for any single unit. There are, of course, after-action reports and "lessons-learned" reviews after both real battles and training or testing exercises. These are most often qualitative rather than quantitative in their output in the subject area of interest here.

¹ See, for example, Wainstein, L., *The Relationship of Battle Damage to Unit Performance*, Institute for Defense Analyses Paper P-1903, April 1986, which analyzes extensive data from World War II and numerous subsequent engagements.

To the best of our knowledge, little attention has been given to the problem of measuring objectively how the performance of a military unit changes as a result of a particular type of training.²

This is not to say that there are no data on the performance of troops in particular tasks in which they have been trained. There are extensive data of this kind, involving, for example, the effects of weapon firing or bombing training, or target observation, on scores achieved in those activities. These data emerge mainly from experimentation with and testing of small units, and often under artificial conditions. Indeed, it is necessary to reduce the number of variables in such activities to be able to measure the outcomes and analyze them quantitatively at all. In the few cases of deliberate testing where this constraint has not been applied (e.g., operational tests such as the AIMVAL/ACEVAL free-play air combat tests of some years ago), the variables associated with learning effects were not the object of measurement and were therefore confounded with other results such as overall averages of exchange ratios as equipment configurations and force ratios were changed.

Reliable objective performance data should become available from the engagement of military units at such facilities as the National Test Center, the Warrior Preparation Center and SIMNET. At present, we can only adopt an optimistic attitude that such data will sooner or later become available both for analytical purposes and to give a more reliable basis for planning the amount and types of training needed to improve and maintain desired levels of military performance.

There is no need to belabor the argument. The key point to be made is that the step from the kinds of data that are available to describe the relationships between unit training and the outcome of a battle or a war are scarce, indeed, and the attempt to amass such data from training exercises and similar activities is a costly and, especially, time-consuming affair.

Yet it is important to investigate the issue, because a great deal of money is spent in activities related to unit training and large scale exercises whose objective is to increase the combat proficiency of *total forces*, including the way they use their weapons, the way they

² One example is given in Rowland, D., "Assessment of the Effects of Experience on Combat Effectiveness," contained in *Proceedings of the Symposium on the Military Value and Cost-Effectiveness of Training*, NATO Defence Research Group, Panel on the Defence Applications of Operational Research, Brussels, 29 January 1985.

cooperate with each other in battle tasks, the way they are led, the way they come to terms with their environment, and all the other factors that affect how the battle really turns out. Money spent in this way competes with money for weapon systems and logistic support, and there is no easy way to decide on the relative cost-effectiveness of different allocations--whether the next dollar (or other unit of currency) at the margin should be spent on acquiring the next unit of equipment or on the next training exercise (not to mention matters such as sustainability and support). It is important to recognize in this connection that the nature of the expenditures on training and on equipment is different. Training costs are recurrent, not only with the same units and personnel to build and maintain proficiency, but with units whose personnel turn over so they must start anew. Weapon and system costs involve initial acquisition and then a continuous stream of operating and support costs. Thus the budgets that might be traded against each other if training and equipment costs are in competition would be different in terms of the time constants and forms of the cost streams. The possibilities of making the trades are not invalidated by these differences; they are simply made more complex.

C. APPROACH

The approach tested here is to seek a blend of quantitative and qualitative understanding by combining one kind of quantitative analysis often used to evaluate weapon systems as parts of forces--the use of large-scale computer simulations of warfare--with the qualitative knowledge of field commanders. This blend might then be used to test whether a quantitative value can be assigned to unit training in terms of combat outcome, together with the cost of such training, so that the cost-effectiveness of training can be compared with the cost-effectiveness of other ways of enhancing force performance.

The computer simulation used in this experiment is the TACWAR model developed at the Institute for Defense Analyses.³ This model, as it was used here, is set up to "fight" a war between NATO and Warsaw Pact forces in the Central Region of Europe. The model represents a frontal war based on exchange of resources; it does not include maneuver or free-form decisionmaking by commanders, but it does constrain sectors to maintain certain realistic relationships with each other by permitting control of front-to-

³ Kerlin, Edward P., *The IDA Tactical Warfare Model: A Theater-Level Model of Conventional, Nuclear and Chemical Warfare*, Institute for Defense Analyses Report R-211, November 1977.

flank ratio by sector, and it keeps track of all exchanges of resources that might result from interactions among weapon systems and their units in wartime. It can represent forces on the offensive or the defensive, and it comprehensively reflects the arrays of forces in the eight Corps sectors of the Central Region and their facilities such as rear support areas and air bases. It includes ground and air combat in all the sectors across the front from the North Sea to the Austrian border. Weapons are in appropriate organizational units up to Division size, with each weapon firing at and vulnerable to all the weapons with which it could interact in actual warfare, and aircraft are in squadrons performing all the missions that aircraft would have to fight in such a war. The model assigns reserve forces according to built-in decision rules; such rules also determine when each side goes on the offensive or the defensive. Allocation of reserves and the decision to take the offensive can also be controlled manually. The data base in the model as it was used here describes NATO forces as they are expected to be configured and equipped in the early 1990s. The data base is not described in detail here, in order to keep this paper unclassified. It was not changed during the analysis, except in controlled ways that will be described.

Model parameters were changed to reflect performance of weapon systems as the units that use them are assumed to be more or less proficient, with the changes in the ranges of parameters taken to represent changes in proficiency that could result from more or less good training. The outcomes of the "wars" fought with the different parameter values were then reviewed for reasonableness in terms of the implications for the interactions between training and the outcomes of the wars. Some further explorations were undertaken to separate effects that might be attributed mainly to properties of the model from those that might fairly be considered to result from training. The results of the model runs were then reviewed to see what the implied effects of training on the outcome of a battle or a war might be.

The next steps are to:

- (1) Inquire of experienced military practitioners whether the extent of unit performance parameter changes that were taken to represent enhanced training, of necessity peculiar to the model used and therefore, probably not ideal to represent or isolate training effects, are reasonable to expect in "real life," and if not, the extent of changes that represent the best that could be expected in the implied circumstances;
- (2) Inquire as to the extent of training (e.g., in duration, number of repetitions and intensity of field exercises) that would be needed to achieve the parameter changes that military judgment suggests are reasonable to expect at best;

- (3) Compare these qualitative data with any quantitative data that can be found that bear on the subject, and either confirm the qualitative data or modify them, checking back with those who made the inputs of military judgment to confirm their views of the reasonableness of any modifications that were made. (Note that if the extent of changes made in the model parameters are judged in this review to be either too large or too small in magnitude, it is possible by this means to obtain better-agreed judgments about the parameter variations that should be used, and then to test for the effects of the revised values in the model.);
- (4) Estimate the cost of training deemed necessary to achieve the effects that are estimated by judgment and confirmed by any existing data to be reasonable; and, finally
- (5) Compare the costs of the training effects with the cost of force and/or weapon system changes to achieve the same effects in the "outcome of the war," the latter to be determined by running the TACWAR model (or other models that may prove appropriate) with parameters changed to represent the force or system changes that achieve the same effects as the training changes (assuming such data about forces and systems are not already available; they may well be).

D. ORGANIZATION OF THE REPORT

This paper describes the "experiment" that was run with the TACWAR model. It then reviews the results of the experiment; it examines effects that might be attributed to the model's design and operation rather than to the effects of training; and then, having made a provisional separation of such effects, it describes the questions to which answers should be sought in the next step of the exploration.

II. DESCRIPTION OF THE "EXPERIMENT"

A. CASES EXAMINED AND VARIABLES CONSIDERED

For convenience in using the model, changes in unit capability were taken for examination that were anticipated to be significant for the outcome of the war, and at the same time presented performance parameters that were relatively easy to vary. It is important to note that the structure of the TACWAR model allows changes describing combat effectiveness to be made only to individual weapon system performance, not to entire units in combat. The performance of units is represented mainly by the rules that determine movement of the FEBA (forward edge of the battle area), appearance of units in combat, assignment of reserves and resupply, and similar matters. Yet the performance of individual weapons and systems determines these measures of unit performance, and they were the logical parameters to change in this investigation. The problem was solved in this case by assuming that the parameters describing individual system performance represent that performance only if the systems operate in units. The reasonableness of this assumption is supported by the fact that the input system performance parameters in the data base are determined at least in part with the aid of historical data that could only be obtained from the performance of systems in units--probability of engagement of fighter aircraft, for example, or probability of locking onto a target during an engagement. In any case, since all the quantitative values are exploratory and subject to change when data are found that represent reality more faithfully, the assumption that weapon performance parameters, though expressed for individual weapons, represent performance when in combat units, seems acceptable for the exploratory phase.

The cases, and the variables changed to represent different levels of training, were as shown in the following table:

Units and Combat Mission	Variables Representing Training Levels
1. Fighter Aircraft Squadrons in Air-to-Air Combat	1. Probabilities of Target Acquisition (P_{acq}) and of Kill (P_k)
2. Aircraft Squadrons in Ground Attack	2. -- P_{acq} and P_k of Ground Targets by Attack Aircraft -- P_{acq} and P_k Aircraft
3. Aircraft Ground Crew Performance	3. Sortie Rates
4. Tank Battalions in Ground Combat	4. --Tank P_k vs. Opposing Weapons --Tank Engagement Rates --Tank Vulnerability to Opposing Weapons
5. Artillery Batteries in Combat	5. -- P_k vs. Opposing Targets --Firing Rates

A 20-day "war" was fought, in each case. As a general matter, the variables were changed arbitrarily for this initial exploration by a factor of two, up or down; and sometimes variables were changed in appropriate combinations (e.g., attack aircraft whose crews are better trained are considered to be able to destroy more ground targets *and* to be better able to evade SAMs). In some cases this kind of variation appeared too simplistic, and the rules for changing the variables became somewhat more complicated. The total "experiment," including the details of the variations that were used to represent the effects of enhanced or reduced training as well as runs to explore effects of the model *per se* (discussed later) are shown in Annex 1.

B. MEASURES OF EFFECTIVENESS

The model outputs yield full information about weapon and personnel casualties on each side; about which weapons did the killing and how much; about the numbers of sorties by mission and engagements by the various units engaged; and other information describing the details of the conflict. All of these were used in the analysis.

The most significant output, however, and the one that best displays the integrated effects of the parameter variations, is the movement of the FEBA [now coming to be known as the FLOT (forward line of own troops), a term not used here as the earlier term is built into the model output]. This movement depends on casualties and other combat history including the use of reserves and the offense/defense posture of each side (which also depends on the status of opposing forces and their combat history). Effects on movement are weighted according to the kinds of systems and units destroyed and they depend on the resulting force ratio at the end of each day of conflict. Therefore, in the discussion of results that follows, the average FEBA position across the front on each day is used as the output measure of interest. The other measures will be alluded to in context when necessary to illustrate a point.

It is worth noting for clarity in interpreting the results that with the array and capability of forces described in the model's data base an attack by the Warsaw Pact always advances the FEBA into NATO territory. All scenarios begin with a WP attack on NATO. Therefore, results that reduce the WP advance signify improvement in the performance of NATO's forces.

III. RESULTS OF THE MODEL RUNS

A. EFFECTS OF UNIT PROFICIENCY ON THE OUTCOME OF THE WAR

1. Overall Results

The results of the initial model runs, expressed as average FEBA movement across the eight sectors of the front, are given in Figs. 1 through 5, discussed below. The detailed figures conveying results in measures other than FEBA position are contained in the Appendix, and are numbered to correspond to Figs. 1-5 of the main text. In a few cases, some of Figs. 1-5 are repeated, with "local" numbering, in the Appendix, to maintain the continuity of text references. The results of the individual "tests" or "wars" are self-evident from inspection of the figures. Since the FEBA typically advances into NATO territory under the initial conditions of relative strength of the two sides in the model as set up for the base case, a reduction of FEBA movement signifies that the changes in the parameters taken to represent training effects have made NATO forces stronger and they have therefore held more territory against the WP attack. If the FEBA position after some period of conflict returns to zero, that signifies that NATO has repelled the WP attack and the original border has been restored. The sooner the border is restored, the stronger the NATO forces were made by the changes to them. If the border is not restored but the FEBA ceases to advance into NATO territory, then the attack was held at the time the curve of FEBA advance becomes level, but NATO forces were not strong enough to restore the border (or were prohibited from doing so by rules of the model for the "war" in question--a case that will be examined later).

The results show that, as a general matter, assuming effects signifying reduced Blue training has a much smaller impact than assuming effects signifying enhanced Blue training. This occurs because the FEBA is advanced by the Red side in the base case nearly as fast as it would advance if there were no opposition at all; it is a result of the base-case data describing force capability in the model. Regardless of the reason, the case of

reduced training is of little interest in this context, and only the enhanced-training results will be discussed in what follows.

Overall, the results in Figs. 1-5 (and data in the Appendix to be discussed later) show that:

- The effects on the simulated war of unit proficiency in carrying out a greater number of aircraft sorties *per se* (either by destroying more enemy aircraft while losing fewer of one's own, or by training of ground crews, improving their equipment, and having enough pilots so that more sorties can be flown) were small in the model outputs. This probably occurred because the combination of sortie allocations to targets and kill probabilities against those targets that were built into the model did not have a significant enough effect on the ground battle. However, such effects are difficult to measure in this model, as will be discussed below, even though the effects on sorties flown of changing air-to-air effectiveness, or of changing sortie rates directly, as surrogates for improved unit proficiency derived from training, can be measured easily as direct outputs of the model.
- Increasing effectiveness in killing ground forces and in preserving the weapon systems and the forces that kill ground forces do have profound effects on the outcome of the war in the model. A factor of 3 or 4 improvement overall in combined effects (i.e., improving force killing capability while reducing force vulnerability) turns the war around from a rapid NATO loss in the base case to restoring the initial border in the cases that simulate improved force proficiency. (The border is restored in more or less time from case to case, but that variation could be an artifact of the model and is judged not important for current purposes.)

2. Air Combat And Sortie Rates

The detailed results underlying the outcomes of the war portrayed in Figs. 1 and 2 are presented in the multiple graphs of Figs. A-1 and A-2 in the Appendix. The effects of a factor of four improvement, in NATO's favor or in the Warsaw Pact's favor, in the ability of aircraft to destroy the opposite side's aircraft in air-to-air combat are shown in Figs. A-1a through A-1h of the Appendix. (The increase of Pact aircraft at Day 8 in Fig. A-1b and related subsequent figures derives from commitment of reserve air forces, as the data base is currently constituted.) As would be expected, and as shown in Figs. A-1a through A-1d, improved ability to destroy the opposing air force in air-to-air combat keeps more of one's own aircraft available over time and increases the number of sorties flown. Because total sorties flown include air-to-ground as well as air-to-air sorties, the number of

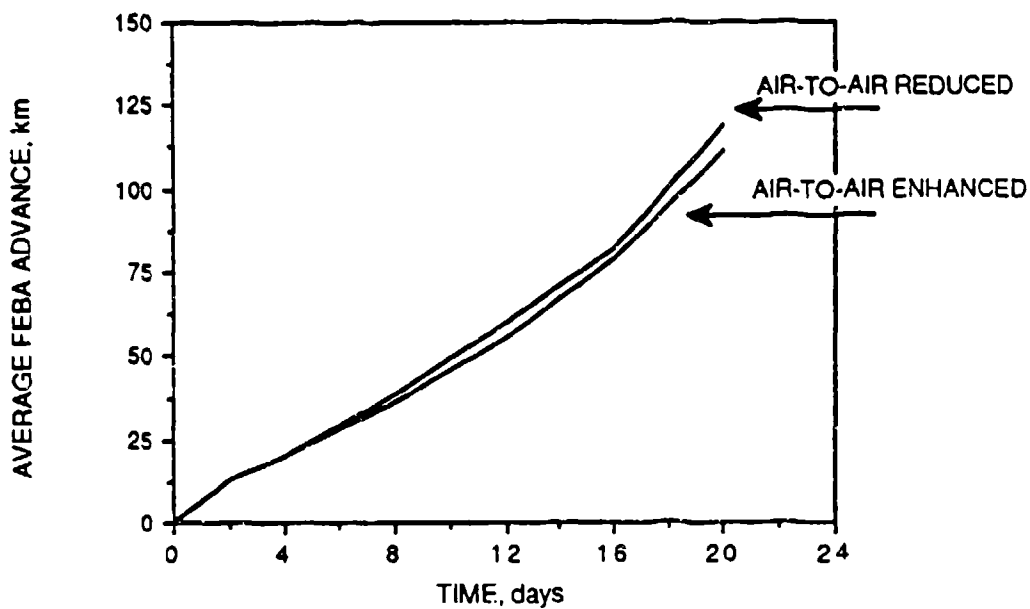


Figure 1. Average FEBA Movement, Air-to-Air Capability Varied

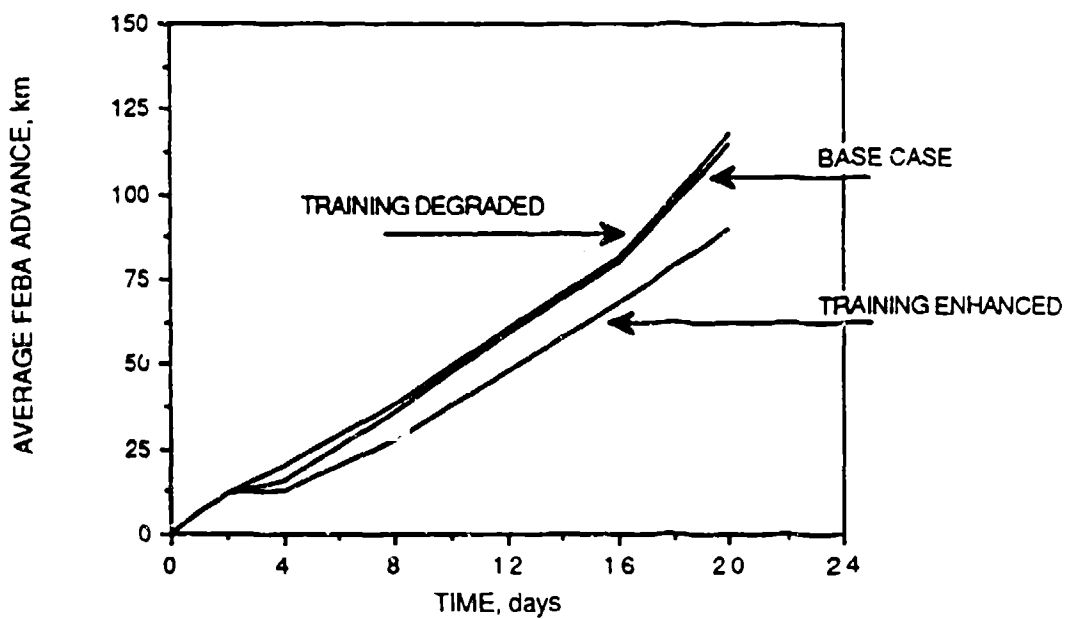


Figure 2. Average FEBA Movement, Training Varied to Affect Sortie Rate

air-to-ground sorties assigned to various missions is also increased, as indicated in Figs. A-1e through A-1h. (Approximately 10 percent of the total sorties flown are devoted to attacking air bases; since the effects are similar to the others shown for air-ground sorties, separate figures are not shown for sorties attacking air bases.) It was noted in (1) above, that the results of the runs that led to Fig. 1 show no change in effectiveness of air-to-ground sorties, only that of air-to-air sorties. When it is considered that the changes in air-to-air sortie effectiveness amounted to a factor of 4, the resulting changes in aircraft available and in sorties flown, amounting to ± 15 -20 percent of total sorties (Fig. A-1c), are not as large as would have been expected. (In all cases, sortie percentages and sortie ratios quoted were calculated from the output numbers of the simulation runs. These numbers, although too extensive to warrant reproduction in their entirety in this report, underlie all the figures and they are available for further research if needed.) Also, as indicated in Fig. 1, the impact on the simulated war of improved air-to-air capability is practically negligible even with an increase of almost 20 percent in air-to-ground sorties. This probably occurs because there is no change in the *effectiveness* of air-to-ground sorties, and the increase in the number of sorties alone is insufficient to turn the balance of forces in the war. This issue will be explored further in later discussion.

From the rules for varying sortie rate directly that are listed in Annex 1, the average NATO sortie rate (Fig. 2) either was increased by 44 percent over a 20-day war, or was reduced by 6 percent over the same period. Only the effect of the increase will be discussed here. This effect was to increase the ratio of total NATO to total Warsaw Pact sorties from 0.89 to 1.5. This is a large change, larger than the change caused by improved NATO air-to-air capability (in that case the NATO/WP sortie ratio increased from 0.89 to 1.3). In this case there is some improvement in the outcome of the war as indicated by a 20 percent reduction in average FEBA movement in the WP's favor (Figure A-2e). This raises the same issues as were raised in the case of increased air-to-air capability about the effect of sorties, alone, on the outcome of the war in this model. It seems clear that flying more sorties alone has little effect on the course of the war, given the overall parameters of the model. Other research on the effect of changing numbers of sorties, alone, by the percentages illustrated here, and perhaps historical data, may suggest that this is not an unreasonable result--that the greatest impact on the outcome of a war between

ground forces that is expressed in terms of territory taken must necessarily appear when the ground force combat parameters are affected directly and in sufficient magnitude.⁴

3. Ground Attack By TACAIR

These results are shown in Fig. 3. It should be noted that the assumed change in unit capability includes not only a change in attack effectiveness but a change in vulnerability of the NATO attack aircraft to Warsaw Pact antiaircraft weapons. A factor of two change in each case led to an overall factor of four improvement or reduction in NATO's capability. In this case, when NATO's air-to-ground attack capability is increased the war turns around; the border is restored. The change in the ratio of total NATO sorties flown to total Warsaw Pact sorties flown is from 0.89 in the base case to 1.3 in the case of enhanced air-to-ground capability--the same as in the case of increased NATO air-to-air capability, and close to that for the case of improved sortie rate. The ratio of NATO to Warsaw Pact air-to-ground sorties increases by a modest amount relative to the ratio of air-to-ground sorties when air-to-air capability was improved; the ratio of NATO/WP air-to-ground sorties (as taken from the underlying computer outputs) was 1.15 for the base case, 1.7 for the case when air-to-air capability was increased, and 1.9 in the case of improved air-to-ground capability. Some of this effect could be due to improved air base attack effectiveness in the model, but that would be small since the air base attack sorties amounted to only about 10 percent of the total number of sorties. It is reasonable to conclude provisionally, from these results, that the main source of improvement in number of sorties in this case comes from increased survivability of ground attack aircraft, and the main reason for the change in the outcome of the war is increased attack effectiveness. This will be consistent with the results for increased effectiveness of ground weapons.

4. Ground Combat By Artillery And Tanks

The effects of improved tank effectiveness (improved by a factor of four, as indicated in Annex 1) are shown in Fig. 4, and the effects of improved artillery effectiveness (improved by a factor of 3) are shown in Fig. 5. In both cases the improvement in force effectiveness restores the border. The improvement in effectiveness for tanks comes from a combination of better kill capability (a factor of two) and better

⁴ See, for example, Salager, F.M., *Operation STRANGLE--A Case Study of Tactical Air Interdiction*, RAND Corp., Report R-851-PR, February 1972.

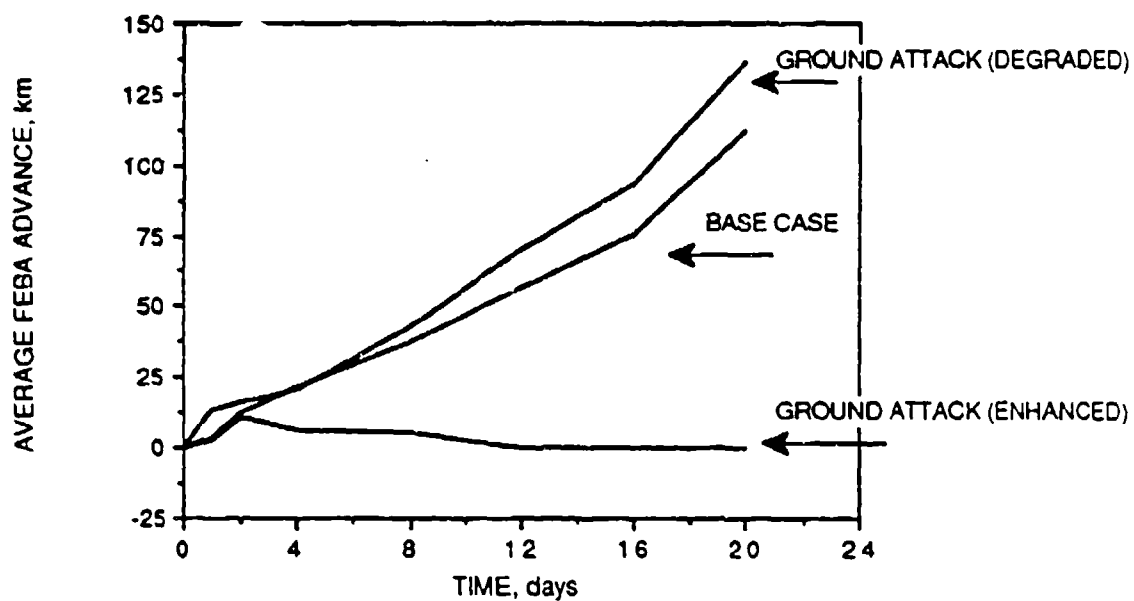


Figure 3. Average FEBA Movement with Variation in NATO Air-Ground Attack Capability

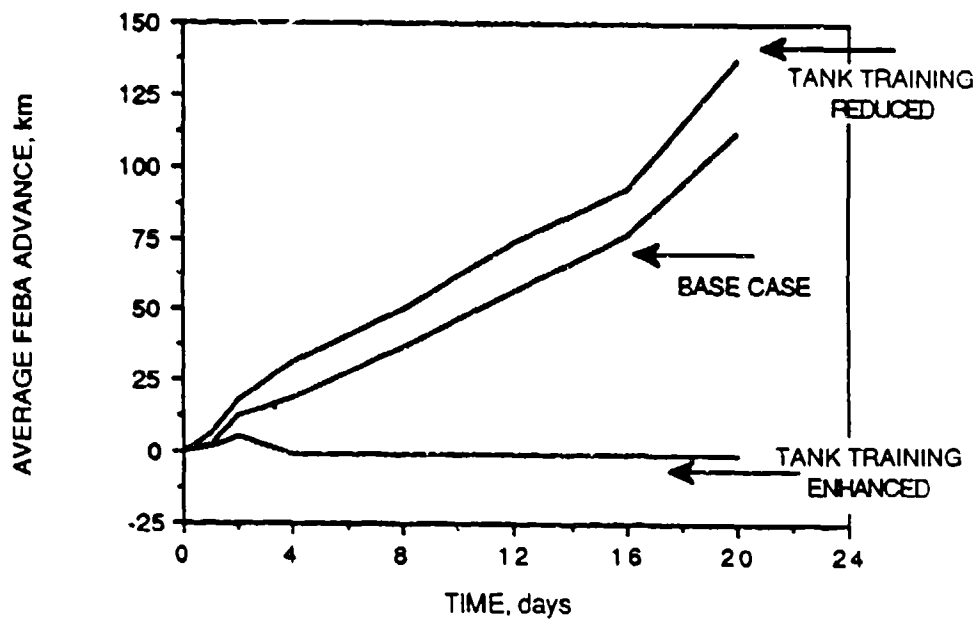


Figure 4. Average FEBA Movement with Variation in NATO Tank Capability Due to Training

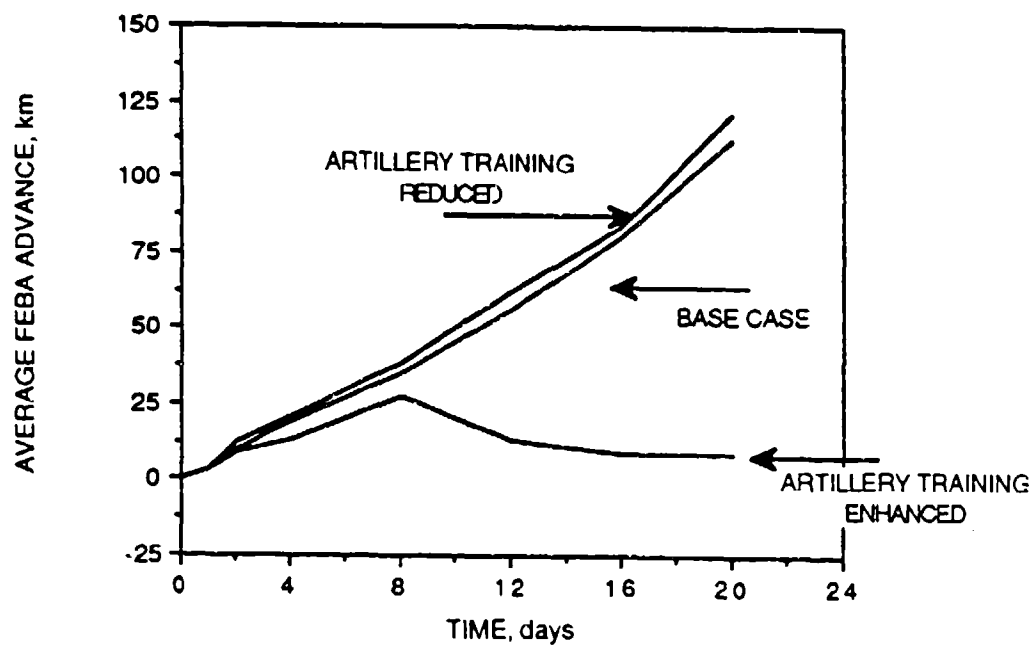


Figure 5. Average FEBA Movement with Variation in NATO Artillery Capability Due to Training

ability to survive (a factor of two). The improvement in artillery effectiveness comes from the ability to fire faster and to get more kills per firing, but not from increased ability to survive. The improved tank capability restores the border sooner than the improved artillery capability in the respective cases. However, direct comparison of these effects is not valid, both because of the way the effects were parameterized and because the actions of the weapons in the model (and in warfare!) are very different. It was for these reasons that the comment was made earlier that the difference in time to restore the border may be of little consequence here.

Examination of the detailed figures in the Appendix suggests that the effects of the changes in tank capability and the changes in artillery capability are similar, and that the main difference between the two cases is in how much Warsaw Pact artillery is killed as NATO weapon effectiveness changes. This is somewhat different over time for the two cases. FEBA advance is related to killing Warsaw Pact artillery in the model by a complex function that also involves the effect of Warsaw Pact artillery in killing NATO weapons; this is one of the reasons that direct comparisons of detailed effects cannot be drawn between the tank and artillery cases. However, since the Pact has a preponderant advantage in artillery, that advantage must strongly influence the course of the battle, and since both tanks and artillery destroy opposing artillery, the reduction of WP artillery attending improved NATO armored *or* artillery unit capability must have analogous effects on the battle, though they may differ in detail.

It should also be noted that for many of the cases where the border is restored (involving air as well as ground weapons) *more* NATO weapons are killed and *fewer* WP weapons are killed when NATO capability is said to be *better* than it is in the base case (see, for example, Figs. A-4e, A-4f; A-5e, A-5f.) This occurs because when NATO's weapons and forces are more powerful, NATO goes on the offensive to restore the border. Forces on the offensive lose more weapons than forces on the defensive; this is consistent with the planning factors in tactical and logistics field manuals (e.g., U.S. Army Field Manual FM 101-10), but it is not always the case. These comparisons illustrate the nonlinear effects in this complex model. These effects must be discussed next.

B. EFFECTS OR ARTIFACTS OF THE MODEL

Despite the nonlinear effects noted, and despite the uncertain effects of the inner dynamics of the model on the overall results, it seems clear that whatever improves NATO's ability to attack and destroy ground targets helps to win the war that this model

"fights." Such an increase in capability in "real life" could easily be ascribed to improved training; the main issue is the size of the effect that should be claimed. The parameter changes made to represent this effect during the initial model runs were apparently very large in relation to overall capability, because their effects on winning the war were dramatic. Before transferring such model results into a search for qualitative and quantitative corroborating data, it is necessary to explore the extent and nature of effects of the model itself in producing the observed outcomes.

One set of runs (D1 and D2 in Annex 1) was undertaken to separate effects like the ability to survive from the ability to kill. Also, since the effects of changes in effectiveness that were investigated *were* so dramatic, another set of runs (E1 in Annex 1) explored how those effects vary as the magnitude of the inputs is changed.

Finally, since the model apparently does not under any of the circumstances examined show dramatic effects on the war of changes in sorties alone, some of the questions posed for the operational community must address the impact of sorties *per se* on the war, although it must also be pointed out that these are controversial matters that have been argued at length after World War II, Korea and Vietnam, and are not settled yet.⁵

1. Separating Kill Effectiveness From Vulnerability

The above results (Fig. 3) showed that doubling effectiveness in ground attack and simultaneously increasing the number of sorties by halving the vulnerability of the attack aircraft to ground fire had the effect of restoring the initial border in 20 days, after the initial fallback under the Red attack. Since in all the air variations the number of sorties was increased by roughly the same amount, it seems a reasonable deduction that doubling the effectiveness of attack aircraft against ground targets might be the key to reversing the war by improved effectiveness of air power (attributed to training in this investigation). Alternatively, it seemed useful to test whether increasing the number of attack sorties by reducing the vulnerability of the attack aircraft, only, might produce greater effects than increasing sorties by the other methods.

⁵ Discussed at greater length in, for example, Andrews, D.R., *Historical Data on the Contribution of Air Interdiction to the Progress of the Land Battle*, presented at 3rd International Symposium on Operational Research, RMCS Shrivenham, September 1986, and Deitchman, S.J., *Military Power and the Advance of Technology*, Westview Press, Boulder, Colorado, pp. 31-35, 1983.

The effect of increasing effectiveness in ground attack by a factor of two, *only*, or of reducing attack aircraft vulnerability by half, *only*, are shown in Fig. 6 as the variation of FEBA position with time. The results show that neither variation by itself is enough to produce the effect of the two together; i.e., both increased effectiveness and reduced vulnerability are needed to win the war. This can still be an effect of the way the model treats the force interactions--the effects of TACAIR sorties are very complex in models such as the one used for these explorations. However, it does not seem unreasonable that both *more* sorties and *more effective* sorties are needed to win. In particular, it would make a difference in the amount of ordnance delivered if attack aircraft are less vulnerable to enemy fire during weapon delivery (which is the effect modeled in the case of enhanced ground attack effectiveness); the greater number of sorties attained this way would count for more than a greater number of sorties achieved by simply "pumping out" more sorties of all kinds.

Figure 7 shows (among other things) the effect of increasing tank effectiveness by a factor of two, *without* reducing tank vulnerability. In this case the war is also won--i.e., here it is not necessary to reduce vulnerability as well as to increase effectiveness to win. The results also show the effect of some variations undertaken to search for the "break point" at which the enhanced effectiveness makes the difference between winning and losing. As can be seen, increasing effectiveness by factors of 1.5 and 1.75 from the base case made little difference, while increasing it by a factor of 1.9 had the same effect as increasing it by a factor of two.

2. Switching From Defense To Offense

The above result showing effects of changing tank unit capability is highly nonlinear, and it is a reasonable presumption that it is produced by some sudden change in the way the war is fought in the model. As noted in several contexts, above, effects such as this are reflected in the details of weapons killed and related matters when Blue takes the offensive in the model. Therefore, the additional runs of E1 in Annex 1 were undertaken. They repeated the variations of Fig. 7, except that Blue was constrained not to go on the offensive; he could only hold his own at whatever point the Red offensive reached.

The results of these runs are shown in Fig. 8. The variation of FEBA position after 20 days with improvement in tank capability is somewhat more regular in this case. However, there is a major change, in that now Blue can only stop the Red attack if he has

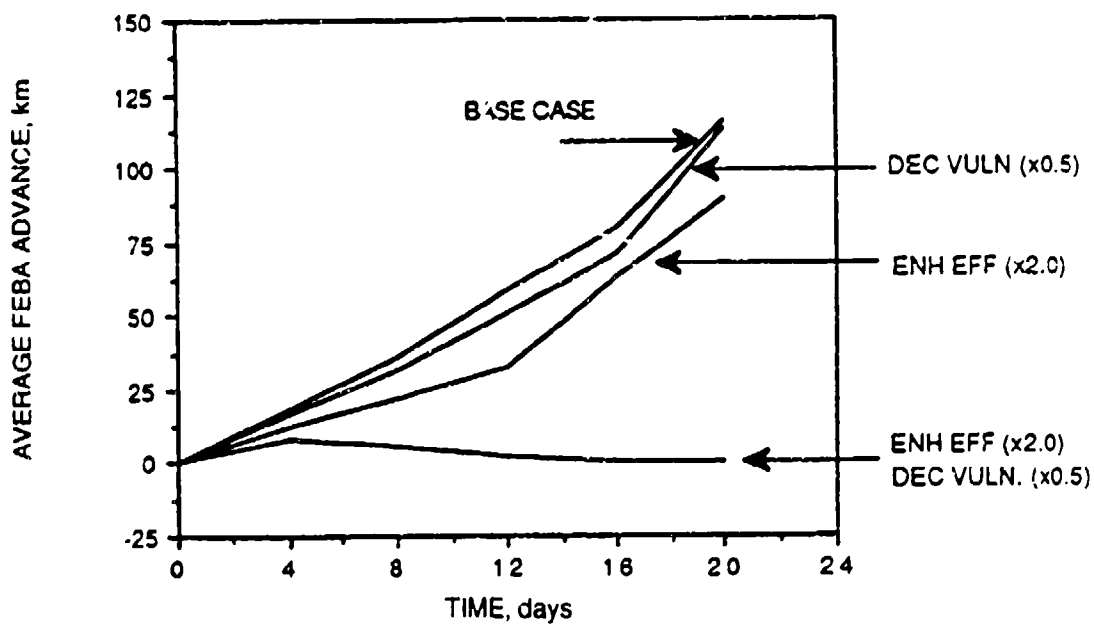


Figure 6. Effect of Separate Variations in Air Attack Effectiveness and Attack Aircraft Vulnerability

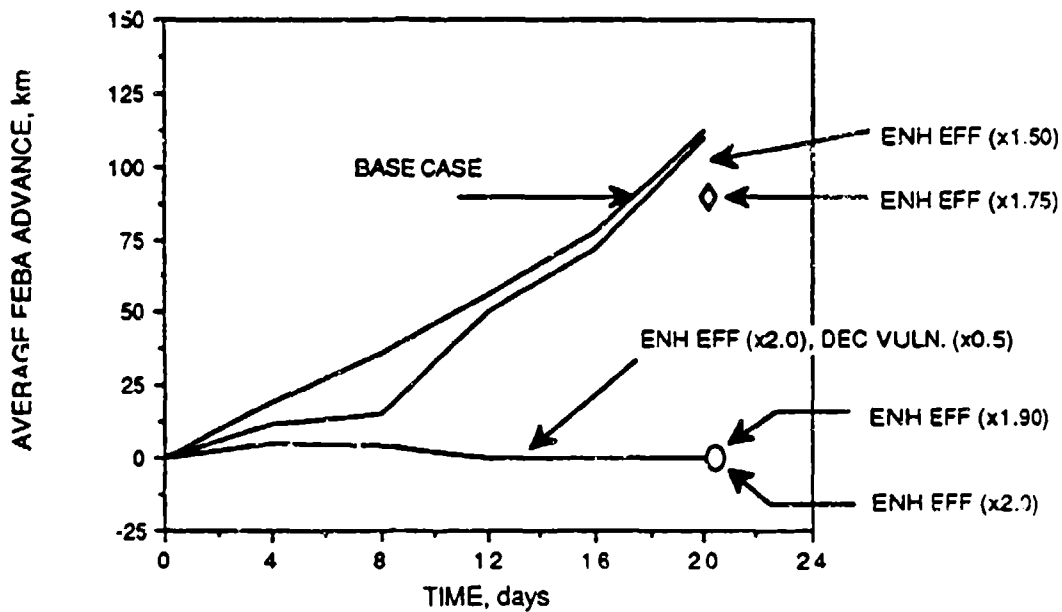


Figure 7. Effect of Separate Variations in Tank Effectiveness (Enhanced) and Tank Vulnerability (Reduced)

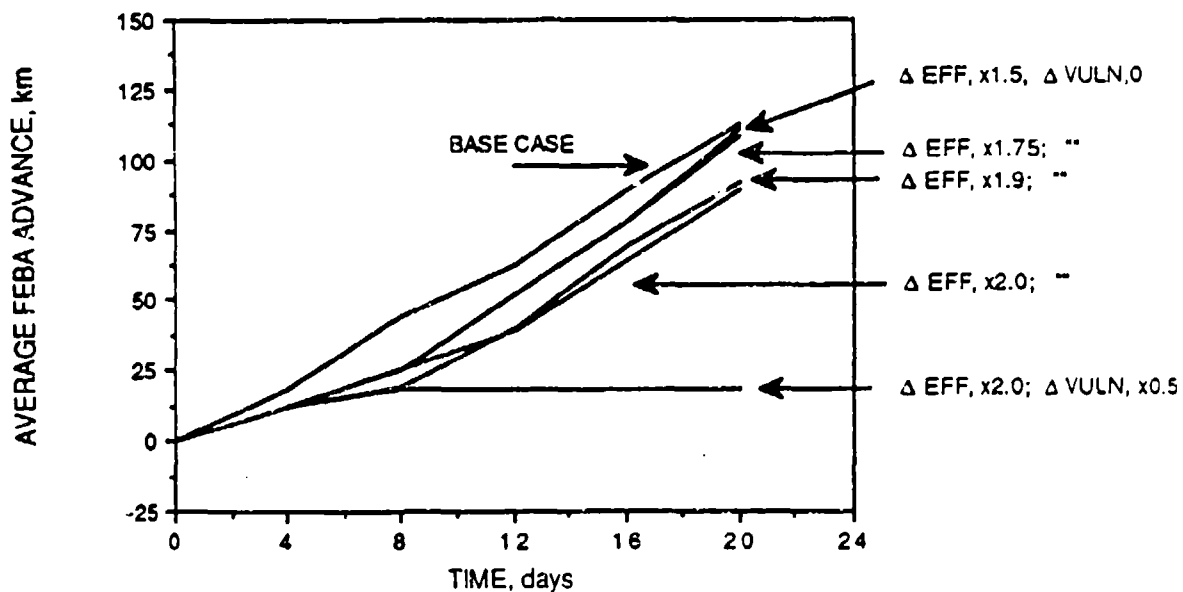


Figure 8. Enhanced NATO Tank Effectiveness (NATO Forces Constrained to Defense Only)

both increased effectiveness *and* reduced vulnerability. This effect is much like that which appeared in the air-to-ground attack variations. It suggests that an increase of air-to-ground attack effectiveness, higher than any that were looked at here, might also be found for which the reduction of vulnerability would not make any difference--Blue would win simply as a result of increased attack effectiveness. The degree of force improvement to achieve this outcome with attack aviation would obviously be different from that for tanks, since the basic weapon effectiveness (in the model and in the real world) is different in the two cases.

It is not unreasonable to infer that similar results would obtain in the case of enhanced artillery capability. That is, there must be a point in the set of parameters that causes Blue to win with enhanced effectiveness only, and a point at which both increased effectiveness and reduced vulnerability are needed. Thus, it appears that the initial, arbitrary choices of parametric variations simply entered different parts of the same kind of functional variation for the different kinds of units examined. These phenomena may reflect a sampling of more orderly behavior of the model, as illustrated in Fig. 9.

C. OVERALL SIGNIFICANCE OF THE MODEL EFFECTS

From the above results and inferences it is possible, and not too risky, to generalize to the effect that all of the parametric variations explored with this model would, at some values, exhibit the following effects in the results of model runs:

- (1) Some combination of parameters signifying enhanced unit training exists that causes a war that Red would have won to be turned around so that Blue wins.
- (2) In increasing order of difficulty, the Blue victory is produced when:
 - Blue becomes effective enough in killing Red forces and in reducing the vulnerability of his own forces to go on the offensive (such results are not uncommon in real warfare--the side on the offensive is more likely to win if it has the resources to sustain the offensive);
 - Blue's effectiveness alone is high enough to permit Blue to go on the offensive and win, whether his force vulnerability is reduced or not; or
 - the combination of increased Blue effectiveness and reduced Blue vulnerability permits Blue to hold the Red side from advancing, even though the "starting" position is not restored because Blue does not take the offensive.

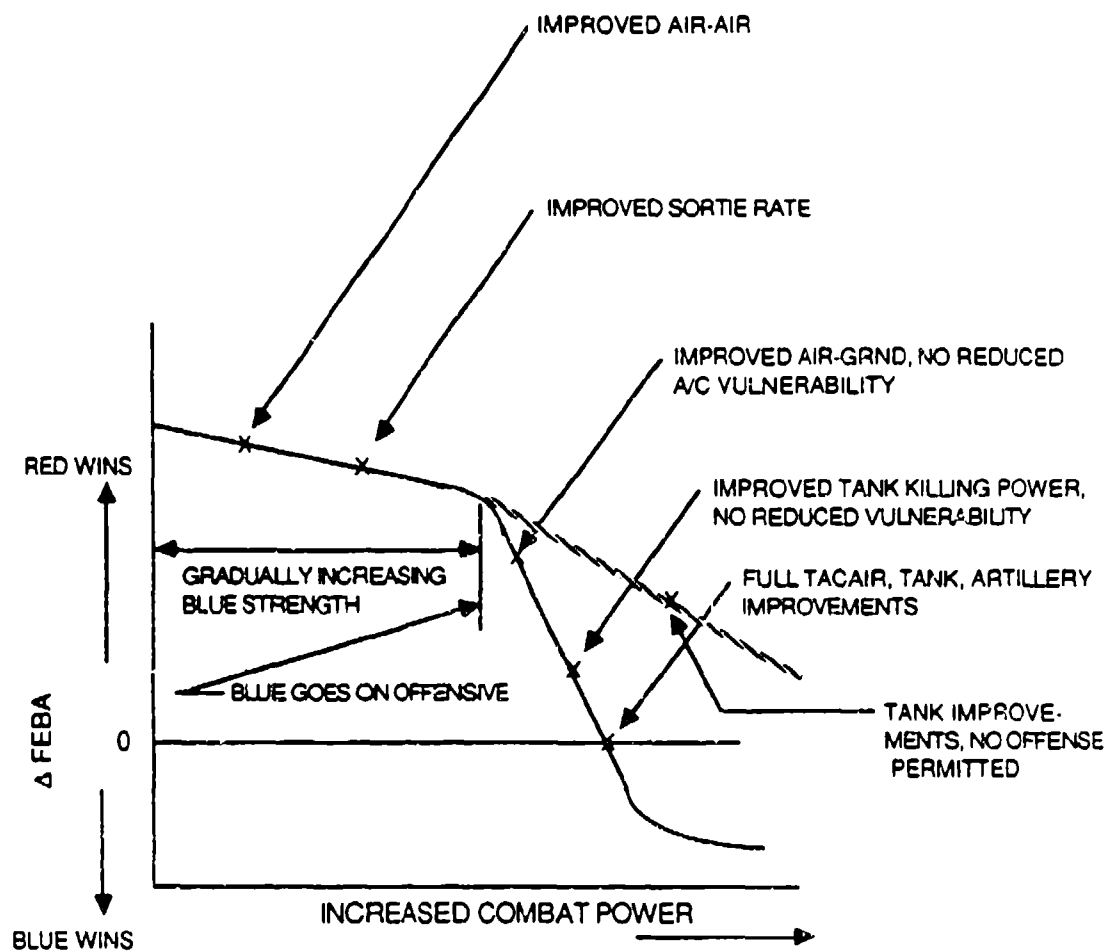


Figure 9. Modeling Nonlinearities and "Sampling" Effects on the Results

It did not seem worthwhile in continuing this "experiment" to spend the time or the resources to demonstrate these effects in fully "closed" fashion by running a complete set of parametric variations with the TACWAR model to reproduce "experimentally" a continuum such as that shown in Fig. 9, because that is not the purpose of this exercise. The model effects cannot be taken to represent the realities of either unit training or actual warfare in any case, even though the results do not conflict violently with conceptual constructs based on actual experience in warfare. However, these explorations suggest that we may be able to use models to learn something about the interaction of unit training and unit effectiveness.

IV. DISCUSSION

The TACWAR model is used generally to improve our understanding of what would probably occur in a European war for cases where the opposing sides have different types and numbers of weapons and troops and might use different tactics. This understanding can then be used to support the acquisition of certain types of improved weapons or simply a larger number of weapons than we now possess to increase the probability that NATO forces could prevail in the event of an attack by the Warsaw Pact. The TACWAR model was, in fact, developed to assist us in making such critical judgments.

The same type of argument is made in this paper, except that differences in system and force performance are assumed to result from better training rather than from the improvement in weapon systems or force structure that are usually considered when using this model. The same type of result is also looked at--that is, what happens to the FEBA when the NATO troops are better trained in ways that would, for example, increase the probabilities of target acquisition, probabilities of survival, or sortie rate or firing rate.

In principle, it is intriguing to contemplate the possibility of comparing the value of acquiring better weapons with the value of better and/or more training or, to be more realistic, with the relative value of various combinations of weapons and training. The main issue is a non-trivial one; assuming that a certain amount of money must be spent at the margin to achieve a desired level of military performance, in what ways should that money be spent? The problem is not, of course, one of training versus equipment. The real problem is to devise some method, some quantitative and credible metric, to assist us in selecting wise and effective combinations. This paper is intended to initiate a path that leads in that direction.

The TACWAR model itself (as well as other available models) should be reviewed with more specific focus on this problem so that we can better understand where training could make a difference and where it could not, in the situations the model represents. For example, tank vulnerability to opposing weapons is a function of design, type of armor and

such; these are fixed characteristics that cannot be altered by any amount of training. However, the way in which the tank is used and how long it is exposed and whether, when exposed, it is covered by other tanks and/or friendly aircraft does affect its vulnerability, and how tanks maneuver in the presence of an enemy can be influenced by training. The same type of argument applies, more or less, to the effective performance of all weapons. In the long run, we would like to be able to account for the variance in the outcome of a battle attributable to the ways in which weapons are used, and therefore, the ways in which they are influenced by training as distinct from the inherent, materiel characteristics of weapons that cannot be influenced by training.

It is interesting to note that improvements in performance due to training should be observable within relatively short periods of time, like weeks to months. The reverse effect, that is, a decline in performance when there is insufficient training, is also true. All of this contrasts strongly with improved performance that can result from the introduction of more advanced weapons, which generally takes more years than we like to contemplate. This means, also, that a proper comparison of improvements due to weapons and/or training should be made over a long term, such as over the life-cycle of a particular weapon system. The different characteristics of the training and the weapon life cycles, noted in Section IB, are pertinent here.

The value of training and comparing its value to that of weapons would need cost data. Data on the costs of various types of training are believed to be readily available, in such terms as the cost of a flying hour for various types of aircraft or for a tank battalion training day or for a steaming hour for particular types of ships, and for the use of the types of ranges needed to collect performance data. No attempt was made to look for such data as part of the present effort. However, such data will be essential for further investigation along these lines.

A most troublesome area requiring investigation is that of the effect of air-to-air combat as perceived in the model results and as expected by military practitioners. As noted earlier in IIIA2, increased air sorties alone, however they are achieved, make very little difference in the outcome of the war in the model used here; the sorties that count are those that destroy forces on the ground, and the effects that count are those that preserve aircraft to deliver more ordnance with increased effectiveness. In particular, enhanced effectiveness in air combat seems to make little difference to the outcome of the war in Europe as described by the model.

For adherents of air power this is counterintuitive, and it also seems to defy historical results that suggest air supremacy as an important contributing factor to victory in major conflicts. It would be of value to gain further insight into the phenomena operating here, to enhance the credibility of the process. In particular, it may be found that air-to-air combat lies on the continuum of nonlinear effects discussed above, or it may be found that the main value of air power--destruction of significant targets on the ground--can only be achieved in a war when absolute air supremacy is established, as occurred in the later parts of World War II and in the 1967 Middle East war. This supremacy may be reflected in, and may be an important part of, the enhanced air-to-ground effectiveness that had such a powerful effect on the outcome in the TACWAR model runs.

V. APPLICATION OF RESULTS: NEXT STEPS

With the insights gained from this "experiment," it is possible to phrase a set of questions for military commanders and other appropriately knowledgeable experts about unit training (to be considered both in terms of military judgment and in terms of available data from prior research), and also about the impact of air-to-air superiority on the outcome of a war, roughly as indicated immediately below.

A. THE IMPACT OF ENHANCED UNIT TRAINING

1. Does it seem reasonable that doubling the ability of units like ground attack squadrons, tank battalions, and artillery battalions to destroy targets, and doubling their ability to survive in battle, would make the difference between winning and losing a battle? A war?
2. Is it reasonable to expect to achieve effects of this magnitude through more effective, more frequent unit training exercises, designed to have longer-lasting effects?
3. If it is too much to anticipate that enhanced training can double both improved effectiveness and reduced vulnerability, what is the greatest capability increase you believe can be achieved by additional training compared with current capability?
4. How would you go about training units such as those examined here to achieve the above levels of capability? (The answers might vary for each kind of unit; separate answers for each would be perfectly acceptable.)
5. Is it possible to achieve both the enhanced effectiveness and the increased survivability through the same set of training activities? If not, what would the differences be?
6. For whatever effects it is agreed can be achieved, in answer to the above questions, how much more than current training would be needed to achieve the effects--preferably expressed in units such as number of exercises per year, kinds of exercises, level of unit involved, etc.

It is assumed that the answers to these questions will give leads to estimation of training activity required to achieve effects analogous to those examined in the

"experiment," at least to the extent that military judgment, reinforced by the available quantitative data, can assess how well the enhanced training would work, and can give some clues as to its required intensity and duration.

B. EFFECT OF AIR-TO-AIR COMBAT

The respondents to the above questions should also be asked their views about the effects of enhanced effectiveness in air combat on the outcome of a battle or a war. The questions in this area should include examination of the significance of gaining air superiority; the impact of carrying out more attack sorties on the morale of opposing forces and their ability to fight; and the effect of air forces surviving longer. Models like the TACWAR model do not capture any of these effects, but the interpretation of results from such models can be helped by informed military judgments in this area.

C. OTHER AVAILABLE DATA

Next, a literature search is in order to find whether data on training exercises exist in a form that would corroborate the judgmental data elicited from the above questions. Extensive data are probably not available; however, even a few data points can serve either greatly to enhance confidence in the judgmental data or to signal problems that will require further, focussed investigation.

D. COST OF TRAINING

With estimates of the extent and kinds of unit training needed to achieve effects of the kind described, it should be possible to estimate the costs of achieving the levels of training elicited, for the various units examined in the model "experiment."

E. RELATIVE COST-EFFECTIVENESS COMPARISONS

Finally, the cost and effectiveness results for training would be compared with similar results for weapon system and force changes that achieve the same or similar effects on the outcome of a battle or a war. Many such studies have been made using the TACWAR model, or other models that may make it easier to simulate imputed effects of training (a single model should be the analytic tool used throughout, once the full investigation is under way, to preserve consistency), so that comparative data should be

readily available; it would not require excessive resources to set up such an examination *ab initio* for the purpose, as long as the same data base is used in the subsequent runs as was used in the runs described here.

ANNEX 1: DESCRIPTION OF INITIAL "EXPERIMENT" PARAMETERS

TACWAR MODEL RUNS DONE TO EXPLORE TRAINING/PROFICIENCY INTERACTIONS

A. Basic test parameters and sequence, all tests

1. Basic runs, with data base and rules for front-flank ratio as they are built in now
2. Parameter changes applied to all NATO forces
3. All runs for 20-day war

B. Measures of effectiveness or output (all displayed vs. days of conflict)

1. Average FEBA position
2. Aircraft available, sorties overall, and sorties by type, as appropriate
3. Number of systems lost in units being tested, and total weapons lost
4. Number of enemy target units killed, by units being tested, broken down by type

C. Sets of runs & parameter variations

1. Fighters in air-to-air combat
 - a. Base Case
 - b. Enhanced Trng--Blue P_{acq} & P_k doubled, Red P_{acq} & P_k halved*
 - c. Reduced Trng--Red & Blue P_{acq} & P_k shifts reversed from base case, relative to (b.)
2. Aircraft in ground attack
 - a. Base Case
 - b. Enhanced trng--Blue P_{acq} and P_k vs. ground targets doubled; Red SAM P_{acq} & P_k vs. Blue attack A/C halved
 - c. Reduced trng--Red & Blue shifts from base case reversed

* Throughout, probabilities of acquisition or kill for the diverse weapons are on the order of 0.1, with some variation according to system type and function. Therefore, doubling or halving probabilities was taken literally.

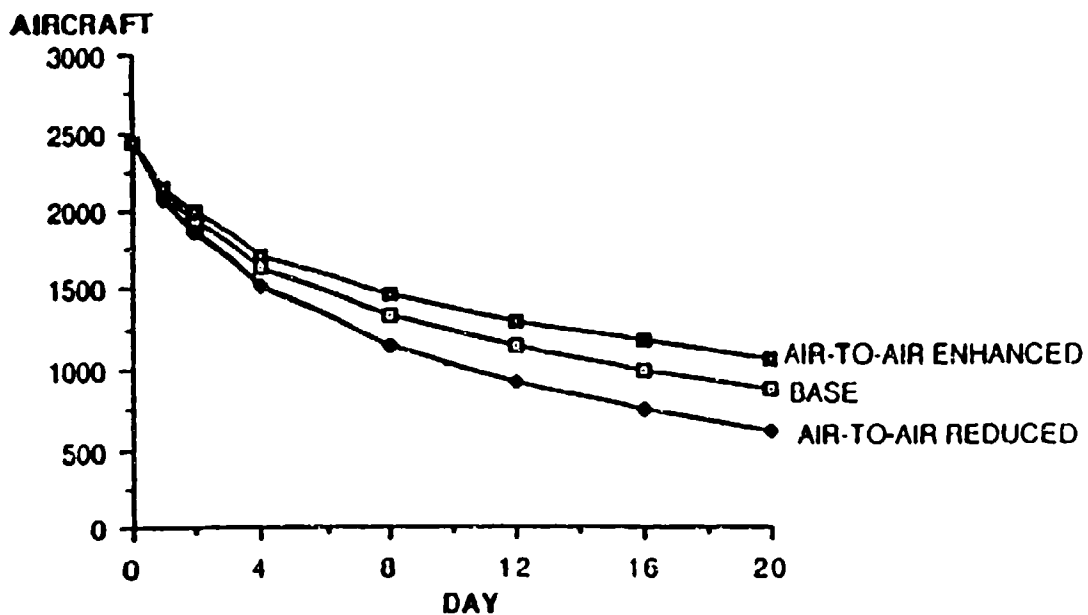
3. Blue A/C ground crew training
 - a. Base Case sortie rates
 - b. Enhanced trng--Sortie rate increased 1 sortie/day, 1st 7 days, 0.5 sorties/day thereafter
 - c. Reduced trng--Sortie rate reduced 0.5 sorties/day, throughout
 4. Tank Battalion in ground combat
 - a. Base Case
 - b. Enhanced trng--Blue P_k vs. Red weapons doubled; proportion of Red tanks in weapon mix engaged by Blue tanks, doubled (subject to the condition, proportion < 0.5 --no change, otherwise); P_k of Red firing at Blue tanks, halved
 - c. Reduced trng--Blue P_k vs. Red weapons halved; proportion of Red tanks in weapon mix engaged by Blue tanks, halved; P_k of Red firing at Blue tanks, doubled
 5. Artillery Bn in combat
 - a. Base Case
 - b. Enhanced trng--Blue firing rate per day, increased by 50%; P_k of Blue artillery vs. any Red target, doubled
 - c. Reduced trng--Blue firing rate per day, decreased by 50%; P_k of Blue artillery vs. any Red target, halved
- D. Separation of enhanced effectiveness from reduced vulnerability effects**
1. Aircraft in ground attack
 - a. Repeat Run C.2.b. above, with P_{acq} and P_k changes only; do not change Red SAM parameters from Base Case
 - b. Repeat Run C.2.b. with Red SAM effectiveness reduced but P_{acq} and P_k not increased
 2. Tank effectiveness
 - a. Repeat Run C.4.b. above, with all parameter changes as given except that P_k of Red firing at Blue tanks is not changed from Base Case
 - b. Repeat D.1 with effectiveness increased by 1.5, 1.75, 1.9, as well as 2.0
- E. Test for effects of nonlinearity in the model (effect of Blue going on the offensive)**
1. Tank effectiveness
 - a. Repeat D.2.a. and D.2.b. with model "locked" so that Blue cannot go on the offensive

APPENDIX

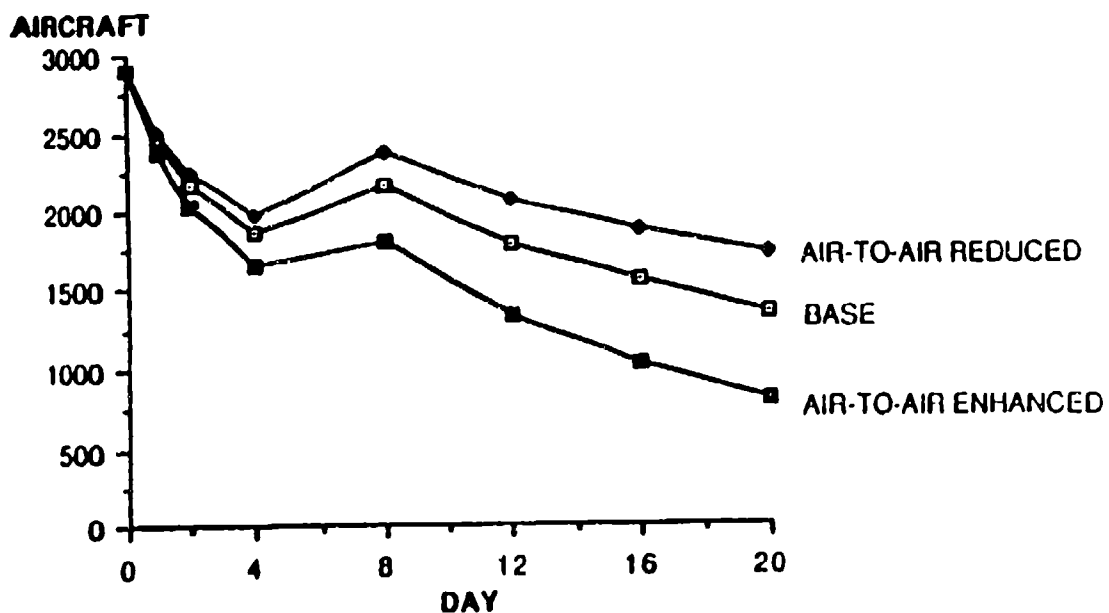
DETAILED DATA FROM MODEL RUNS

APPENDIX--LIST OF FIGURES

A-1.	Effect of Variation in NATO Air-Air Capability	
A-1a.	Aircraft Available NATO	A-1
A-1b.	Aircraft Available Pact	A-1
A-1c.	Total Sorties NATO	A-2
A-1d.	Total Sorties Pact	A-2
A-1e.	Close Air Support Sorties NATO.....	A-3
A-1f.	Close Air Support Sorties Pact.....	A-3
A-1g.	Interdiction Sorties NATO.....	A-4
A-1h.	Interdiction Sorties Pact.....	A-4
A-2.	Effect of Varying NATO Sorties Rate	
A-2a.	Aircraft Available NATO	A-5
A-2b.	Aircraft Available Pact	A-5
A-2c.	Total Sorties Flown NATO.....	A-6
A-2d.	Total Sorties Flown Pact.....	A-6
A-2e.	Average FEBA Movement, Training Varied to Affect Sortie Rate.....	A-7
A-3.	Effect of Varying NATO Air-Ground Capability	
A-3a.	Aircraft Available NATO	A-9
A-3b.	Aircraft Available Pact	A-9
A-3c.	Total Sorties NATO	A-10
A-3d.	Total Sorties Pact	A-10
A-3e.	Close Air Support Sorties NATO.....	A-11
A-3f.	Close Air Support Sorties Pact.....	A-11
A-3g.	Interdiction Sorties NATO.....	A-12
A-3h.	Interdiction Sorties Pact.....	A-12
A-3i.	Total Weapons Killed NATO	A-13
A-3j.	Total Weapons Killed Pact	A-13
A-4.	Effect of Varying NATO Tank Capability	
A-4a.	Total Tanks Killed NATO	A-15
A-4b.	Total Tanks Killed Pact	A-15
A-4c.	Total IFVS Killed NATO	A-16
A-4d.	Total IFVS Killed Pact	A-16
A-4e.	Total Artillery Killed NATO.....	A-17
A-4f.	Total Artillery Killed Pact.....	A-17
A-5.	Effect of Varying NATO Artillery Capability	
A-5a.	Total Artillery Killed NATO.....	A-19
A-5b.	Total Artillery Killed Pact.....	A-19
A-5c.	Total Tanks Killed NATO	A-20
A-5d.	Total Tanks Killed Pact	A-20
A-5e.	Total IFVS Killed NATO	A-21
A-5f.	Total IFVS Killed Pact.....	A-21

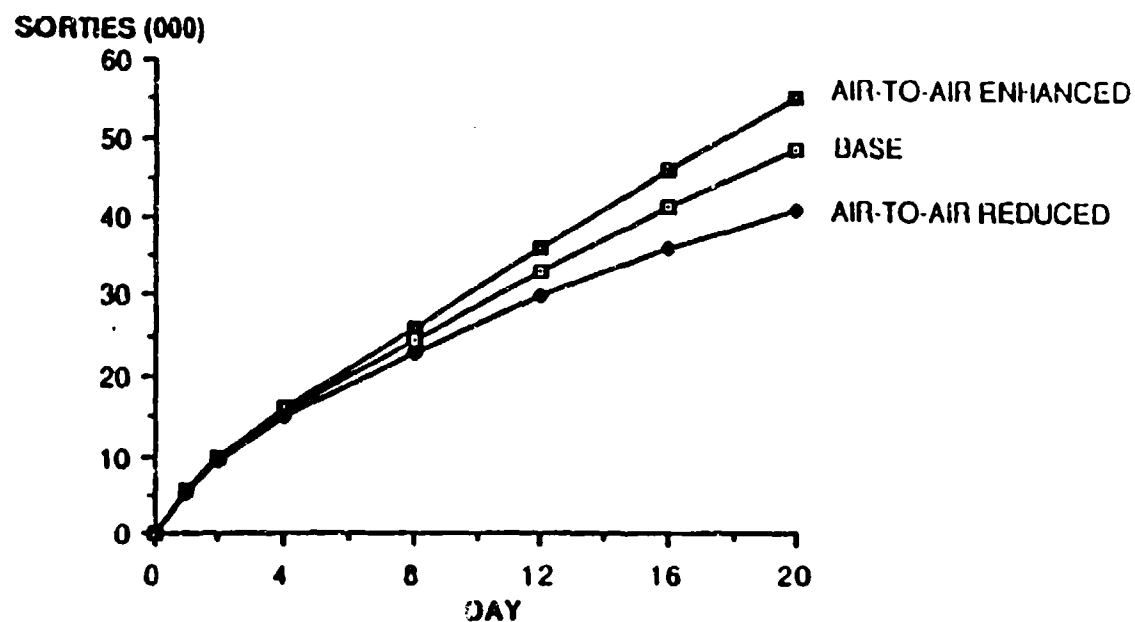


A-1a. Aircraft Available NATO

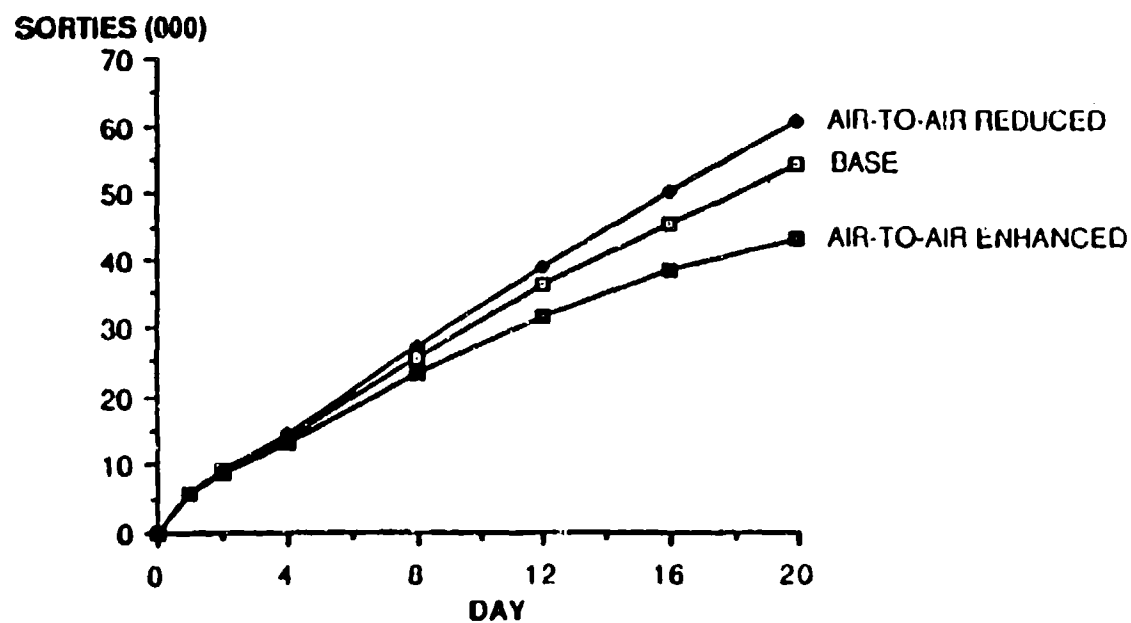


A-1b. Aircraft Available Pact

Figure A-1. Effect of Variation in NATO Air-Air Capability

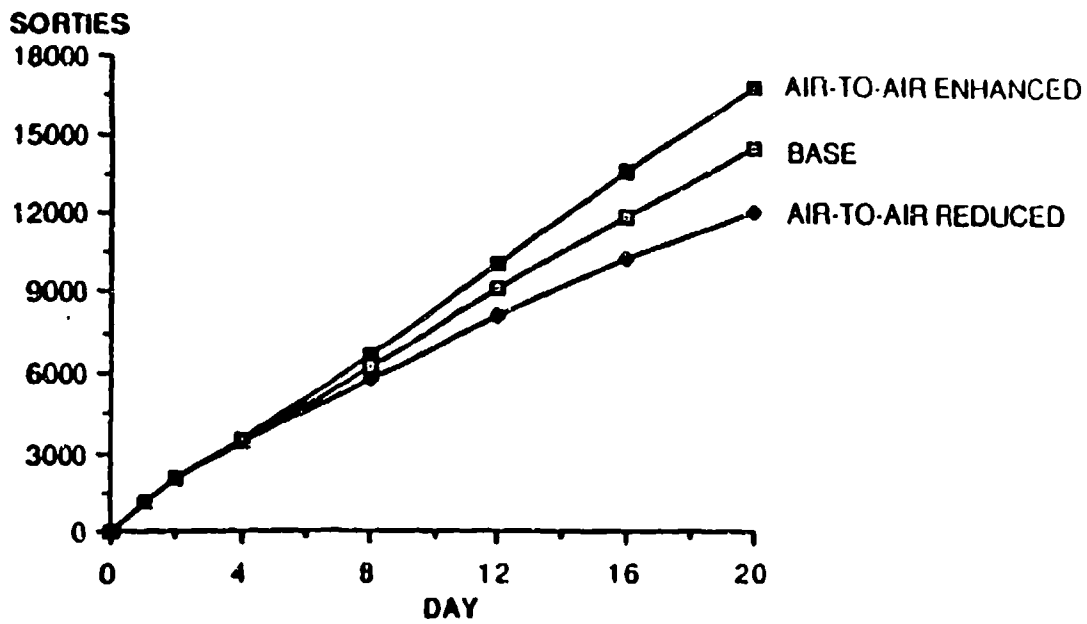


A-1c. Total Sorties NATO

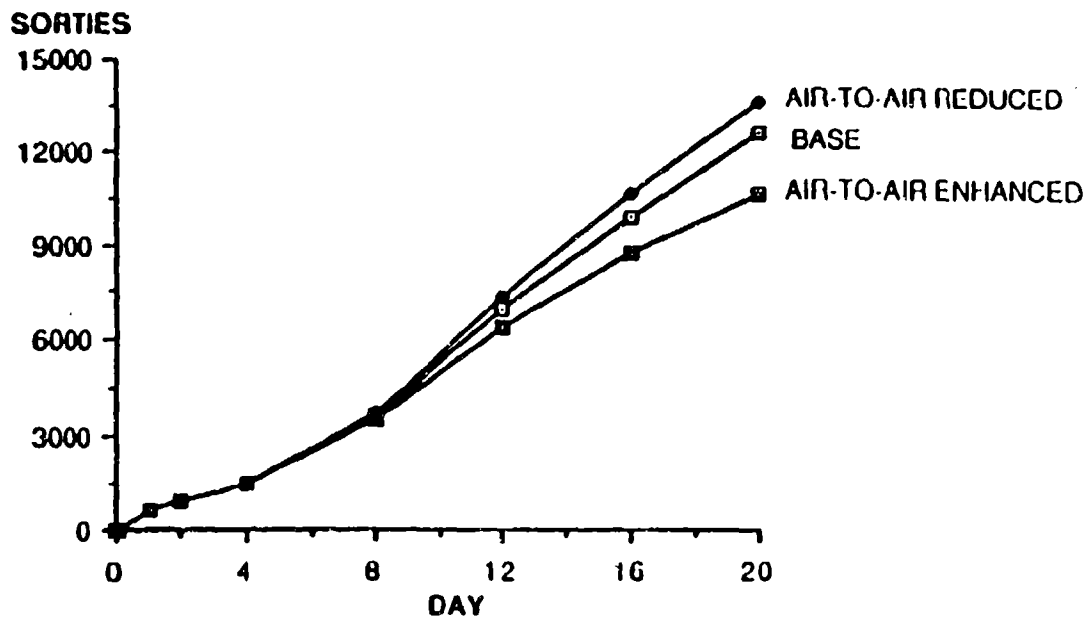


A-1d. Total Sorties Pact

Figure A-1. Effect of Variation in NATO Air-Air Capability (Cont'd)

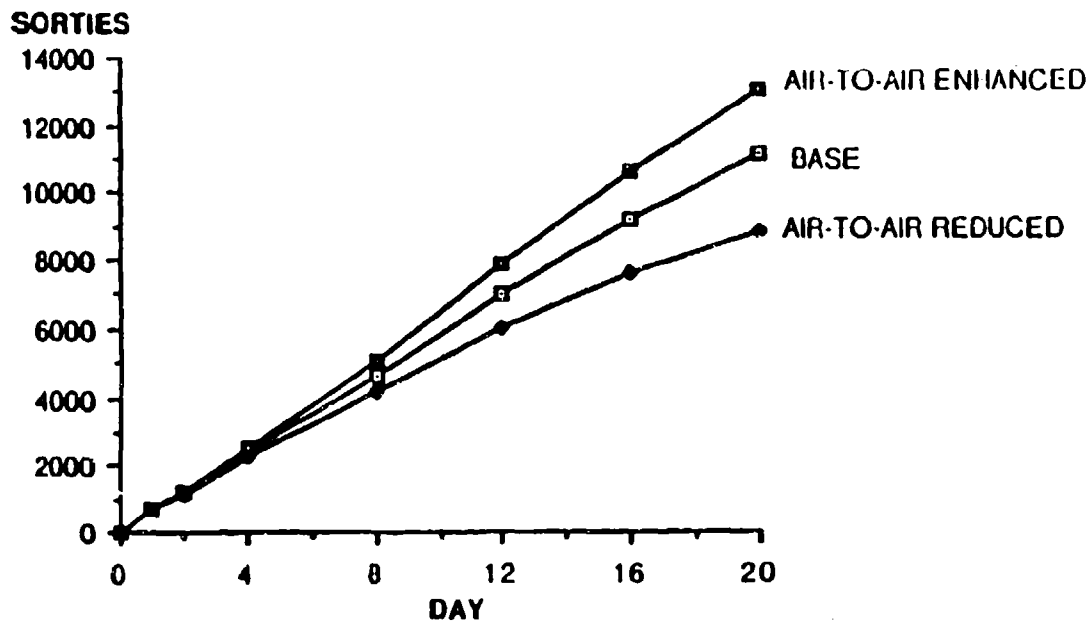


A-1e. Close Air Support Sorties NATO

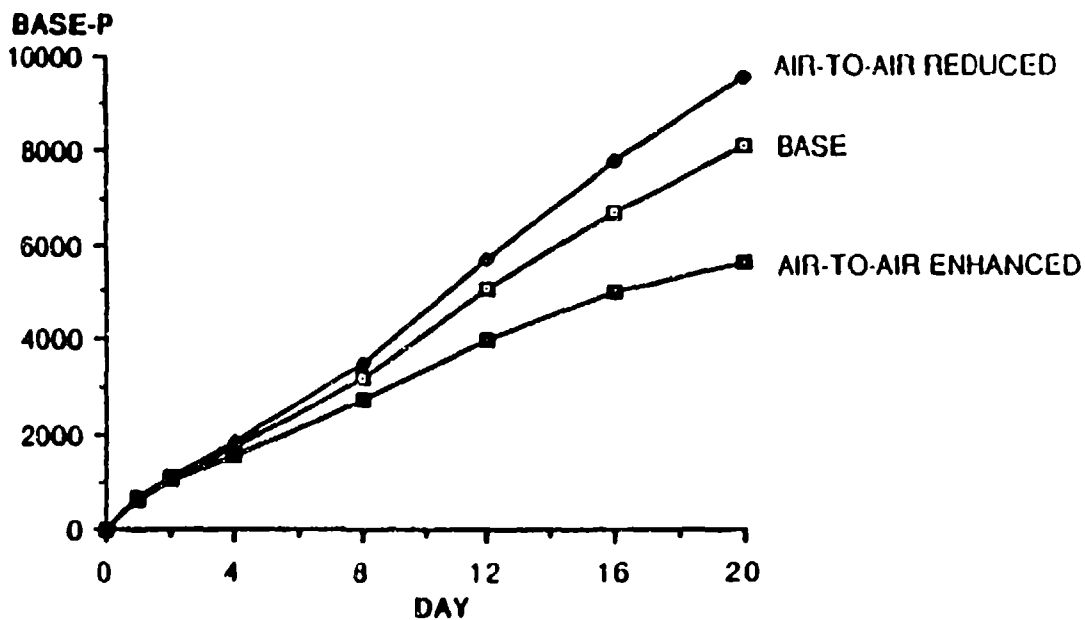


A-1f. Close Air Support Sorties Pact

Figure A-1. Effect of Variation in NATO Air-Air Capability (Cont'd)

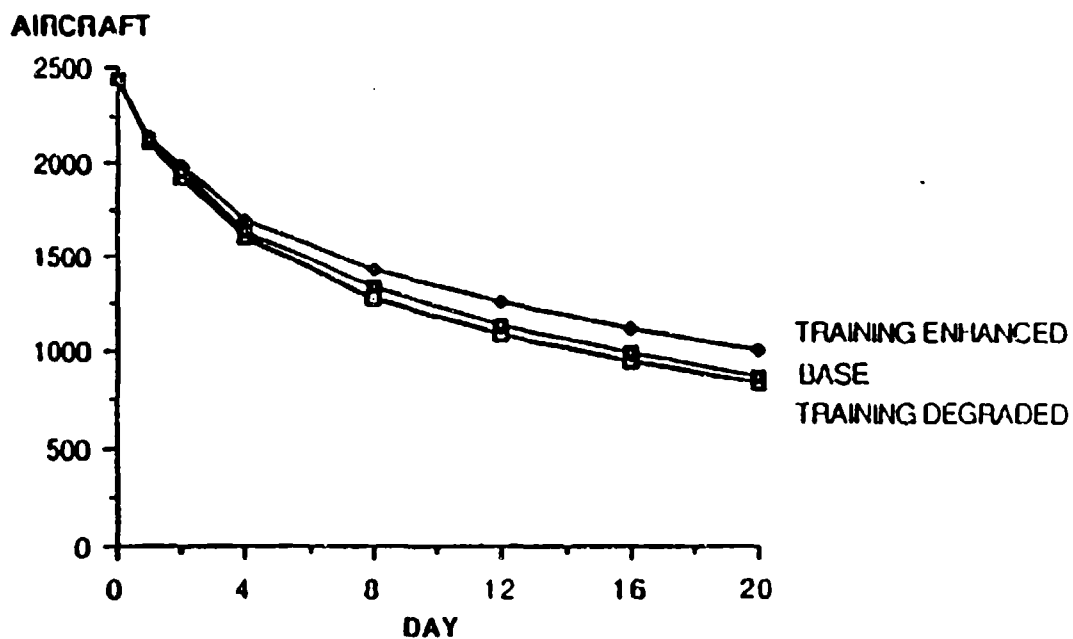


A-1g. Interdiction Sorties NATO

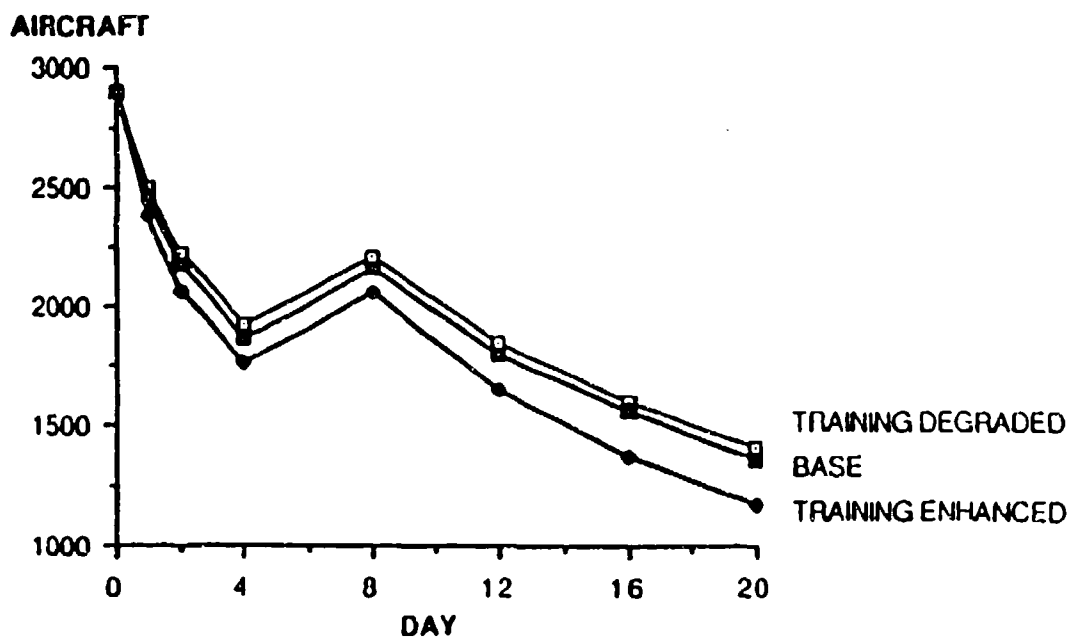


A-1h. Interdiction Sorties Pact

Figure A-1. Effect of Variation in NATO Air-Air Capability (Cont'd)

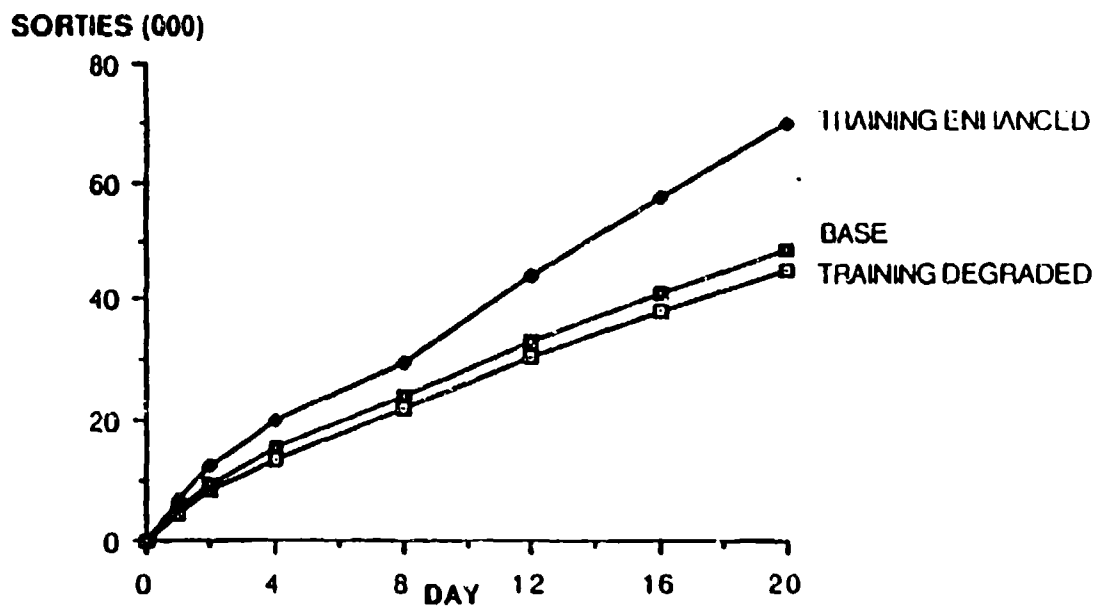


A-2a. Aircraft Available NATO

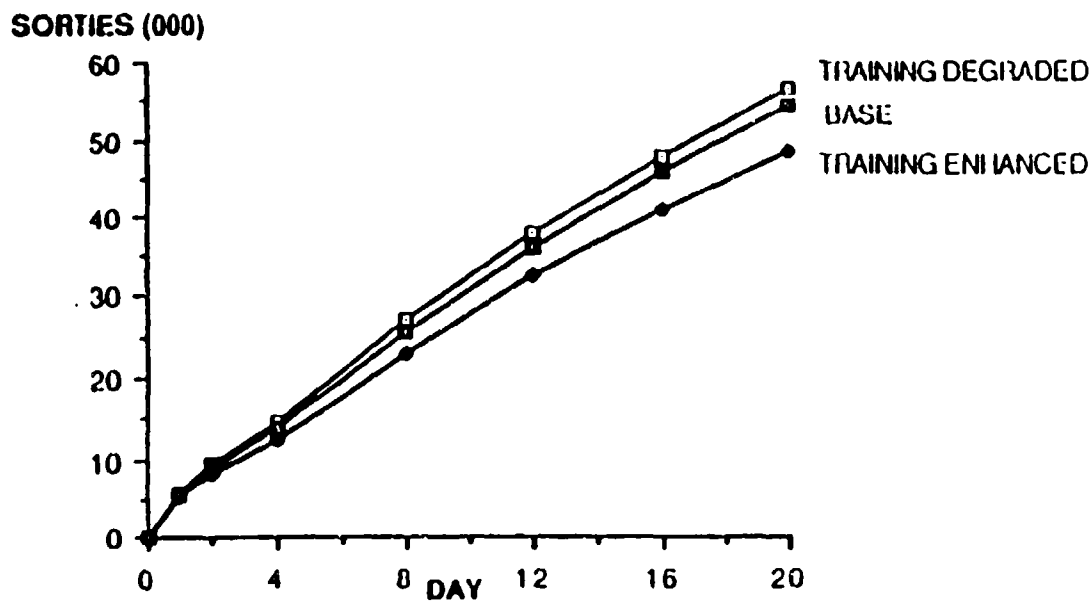


A-2b. Aircraft Available Pact

Figure A-2. Effect of Varying NATO Sorties Rate

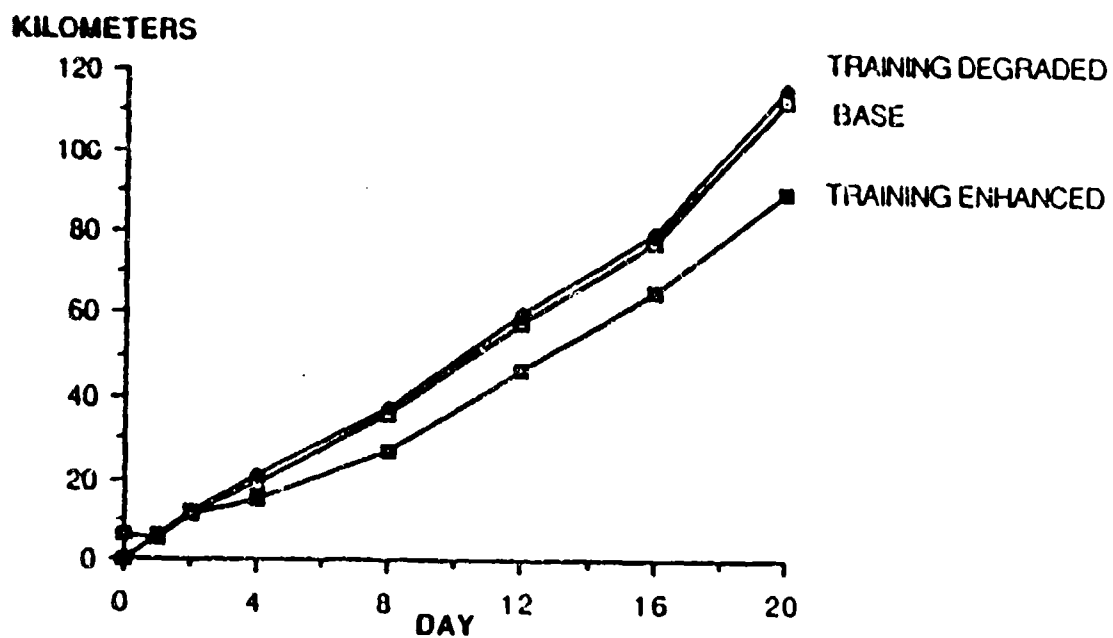


A-2c. Total Sorties Flown NATO



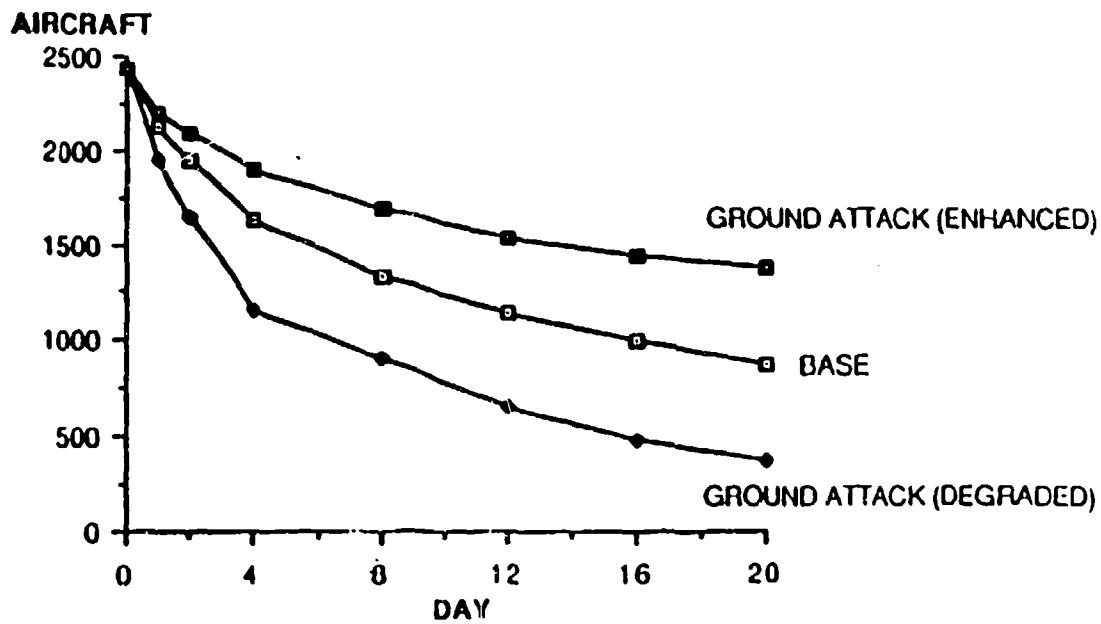
A-2d. Total Sorties Flown Pact

Figure A-2. Effect of Varying NATO Sorties Rate (Cont'd)

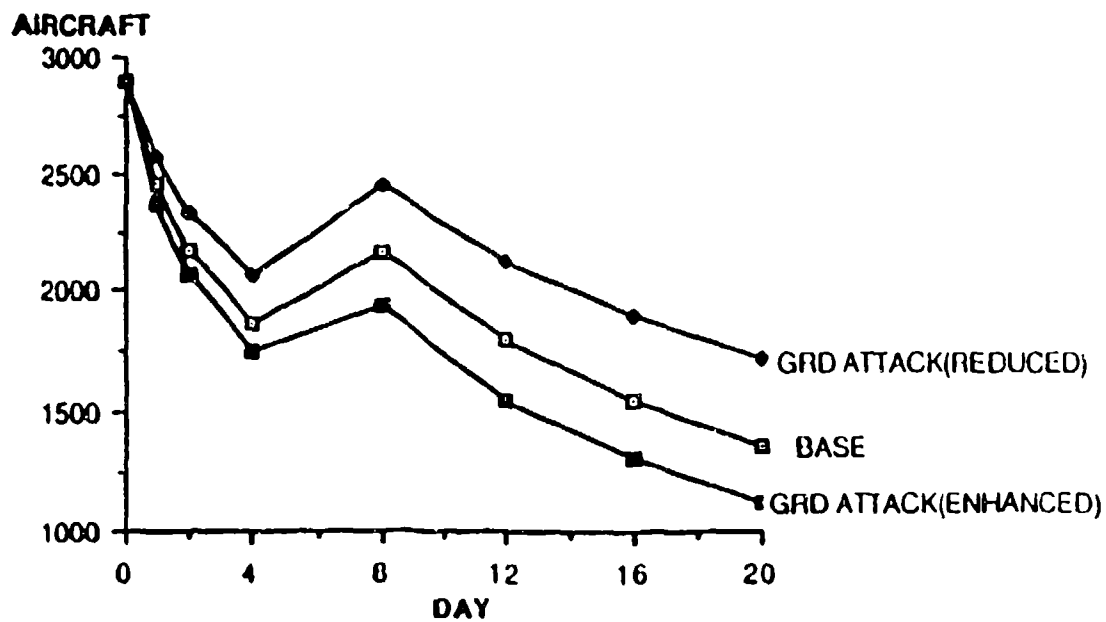


A-2e. Average FEBA Movement, Training Varied to Affect Sortie Rate

Figure A-2. Effect of Varying NATO Sorties Rate (Cont'd)

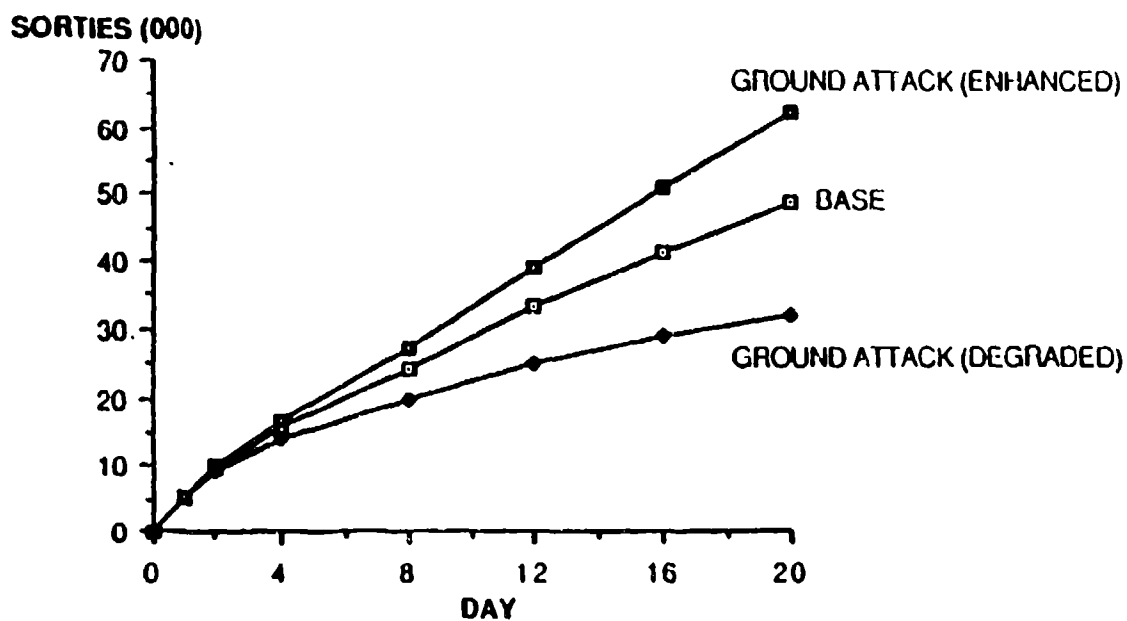


A-3a. Aircraft Available NATO

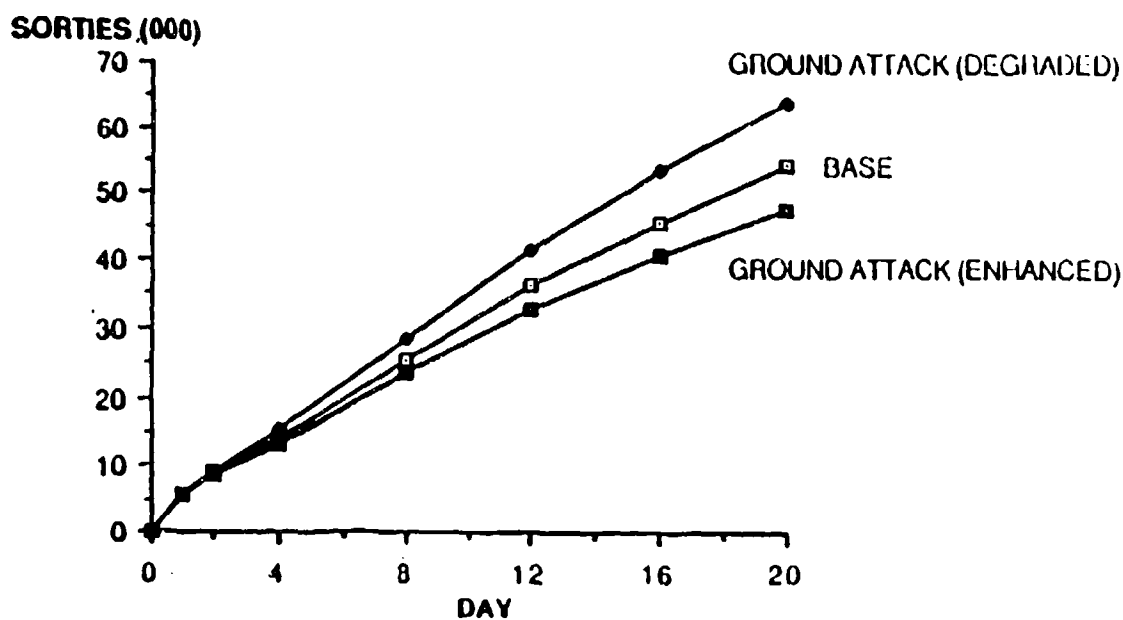


A-3b. Aircraft Available Pact

Figure A-3. Effect of Varying NATO Air-Ground Capability

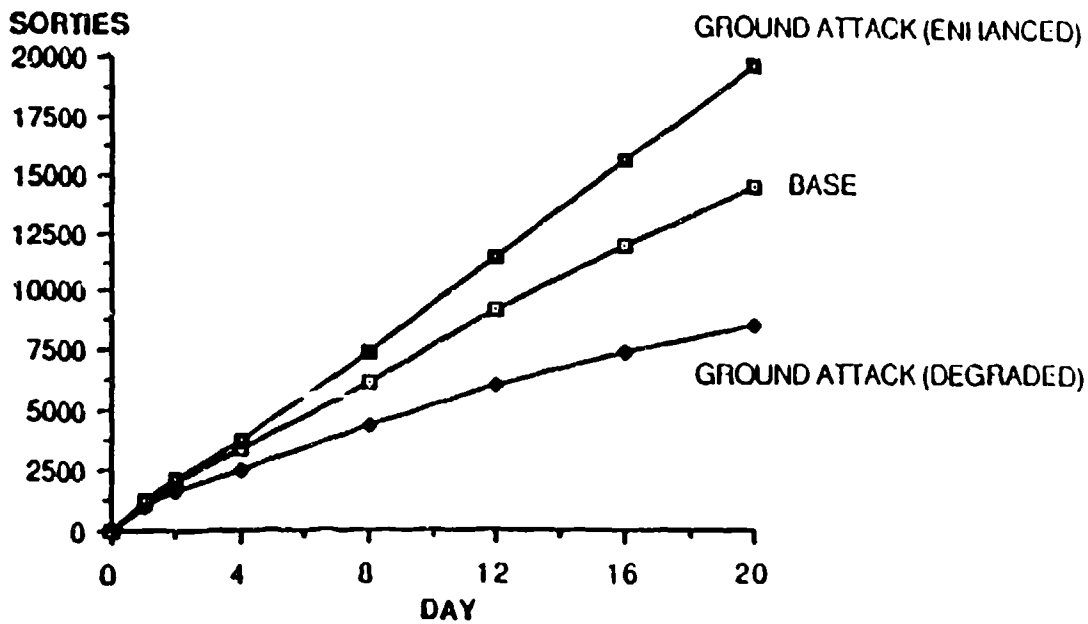


A-3c. Total Sorties NATO

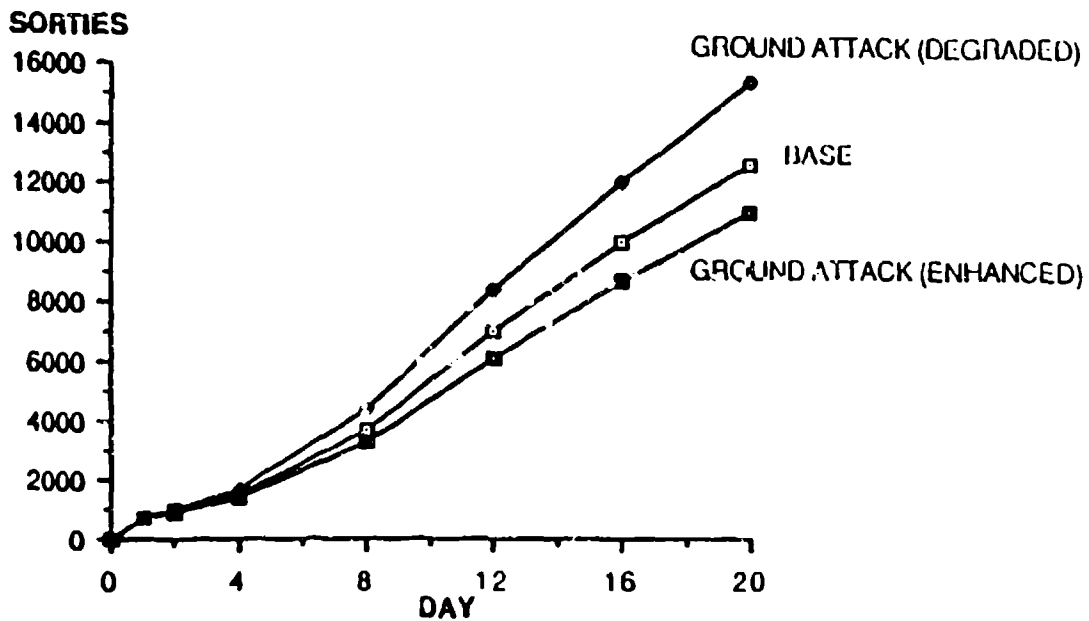


A-3d. Total Sorties Pact

Figure A-3. Effect of Varying NATO Air-Ground Capability (Cont'd)

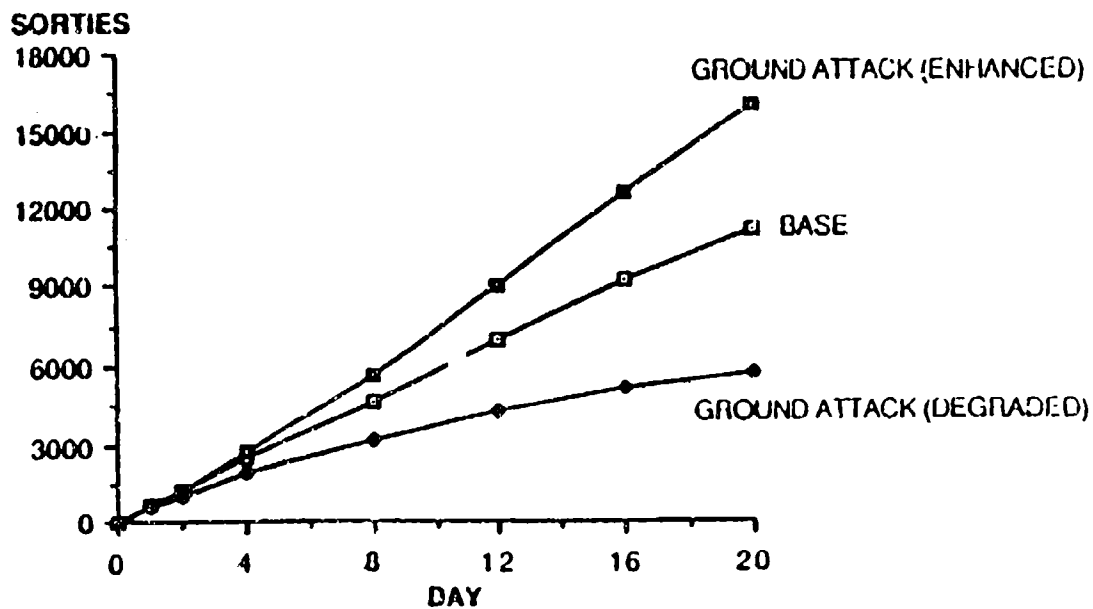


A-3e. Close Air Support Sorties NATO

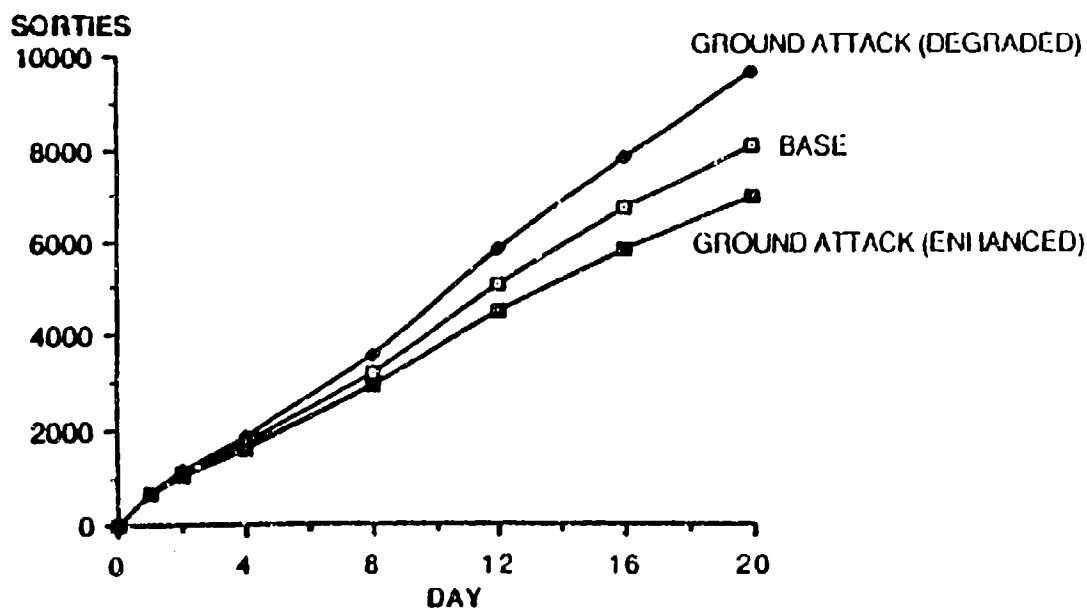


A-3f. Close Air Support Sorties Pact

Figure A-3. Effect of Varying NATO Air-Ground Capability (Cont'd)

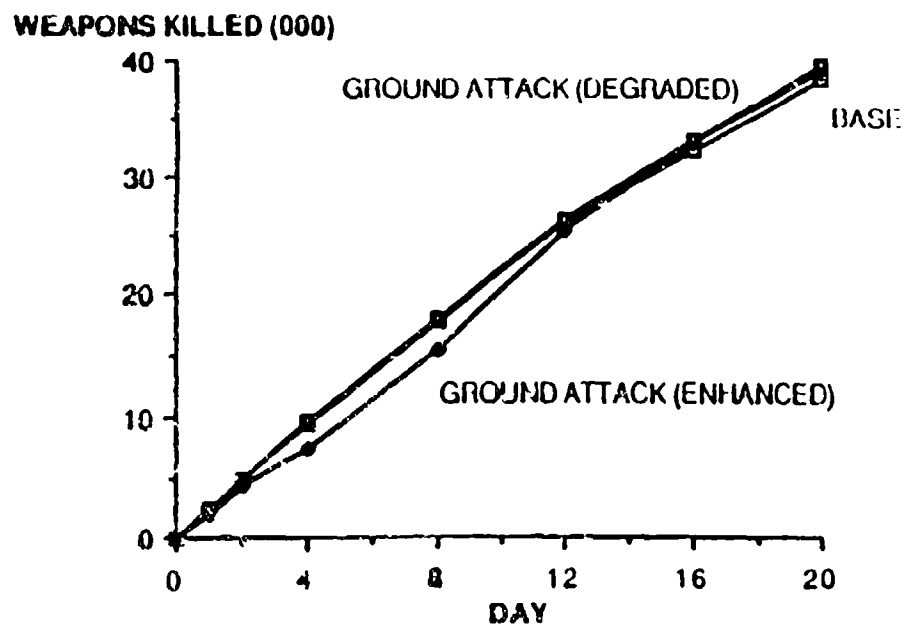


A-3g. Interdiction Sorties NATO

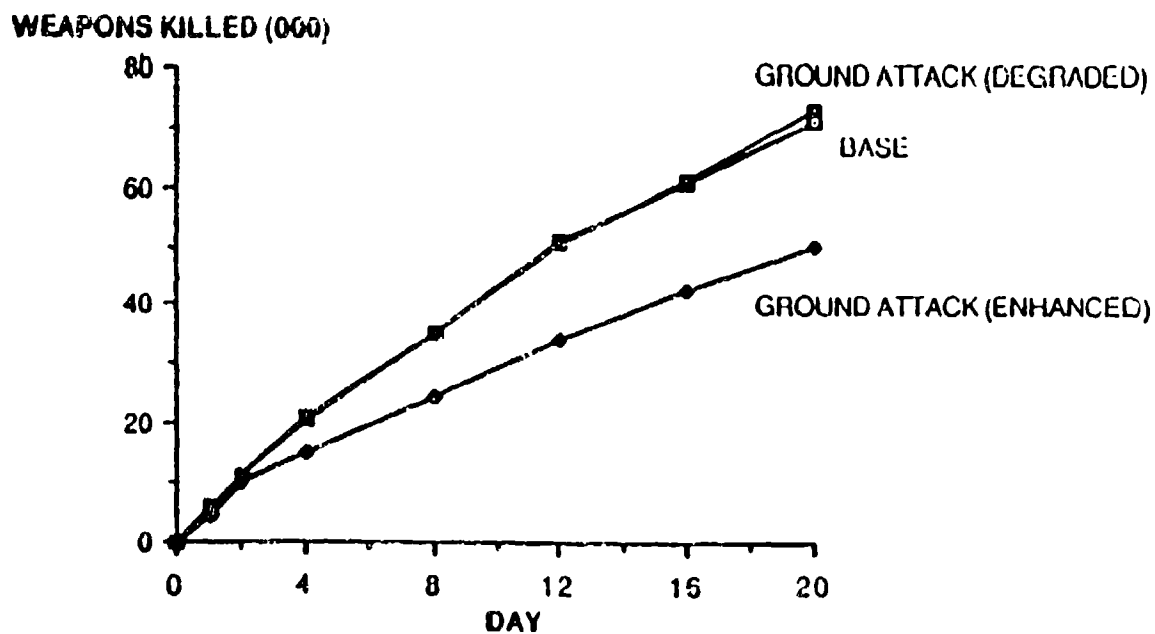


A-3h. Interdiction Sorties Pact

Figure A-3. Effect of Varying NATO Air-Ground Capability (Cont'd)

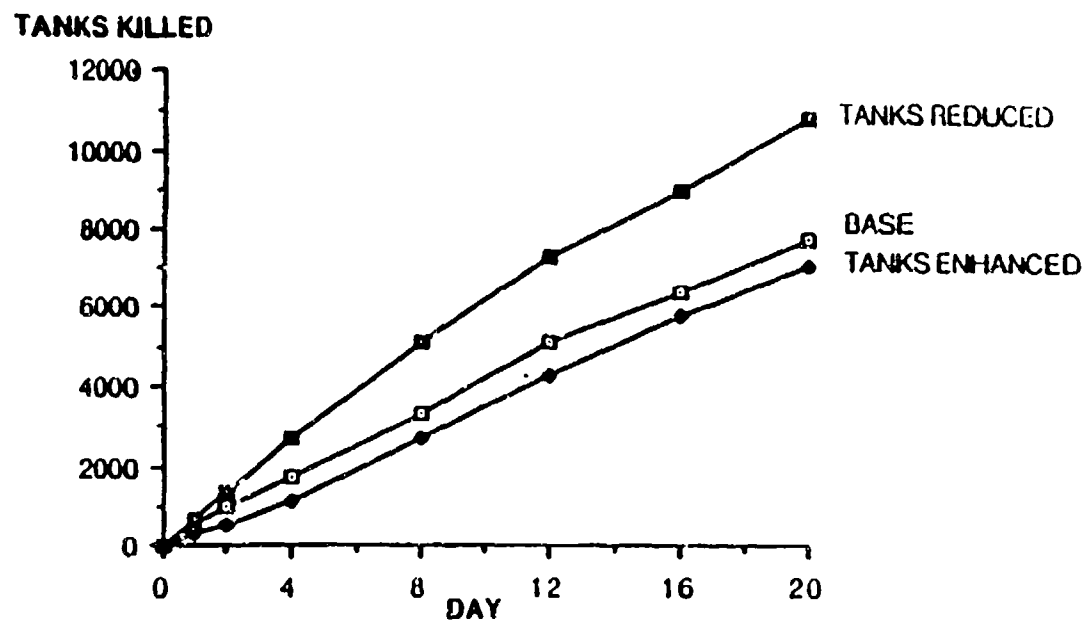


A-3i. Total Weapons Killed NATO

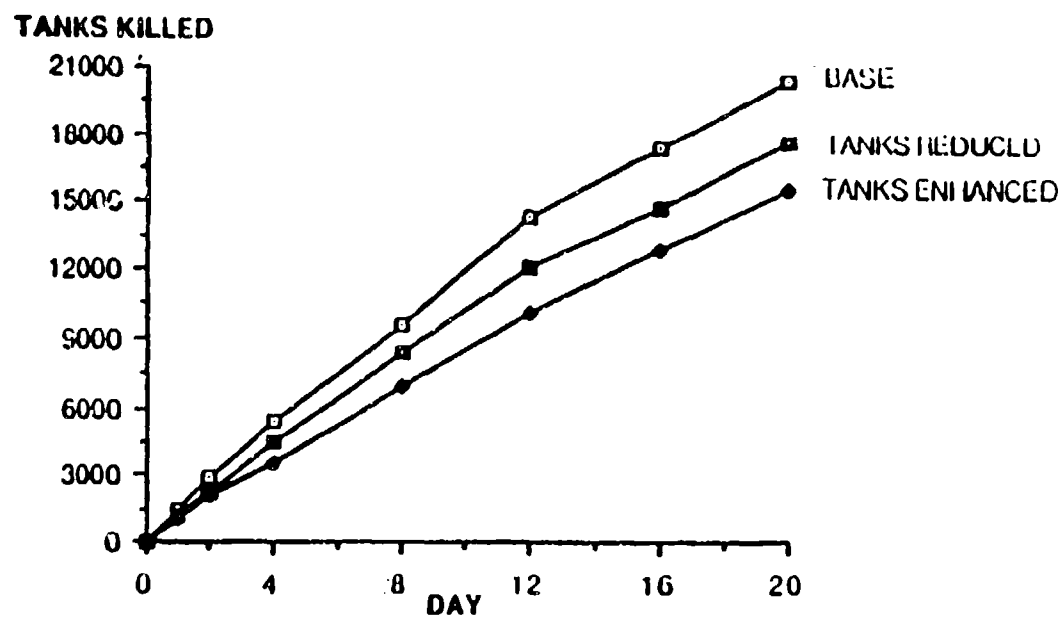


A-3j. Total Weapons Killed Pact

Figure A-3. Effect of Varying NATO Air-Ground Capability (Cont'd)

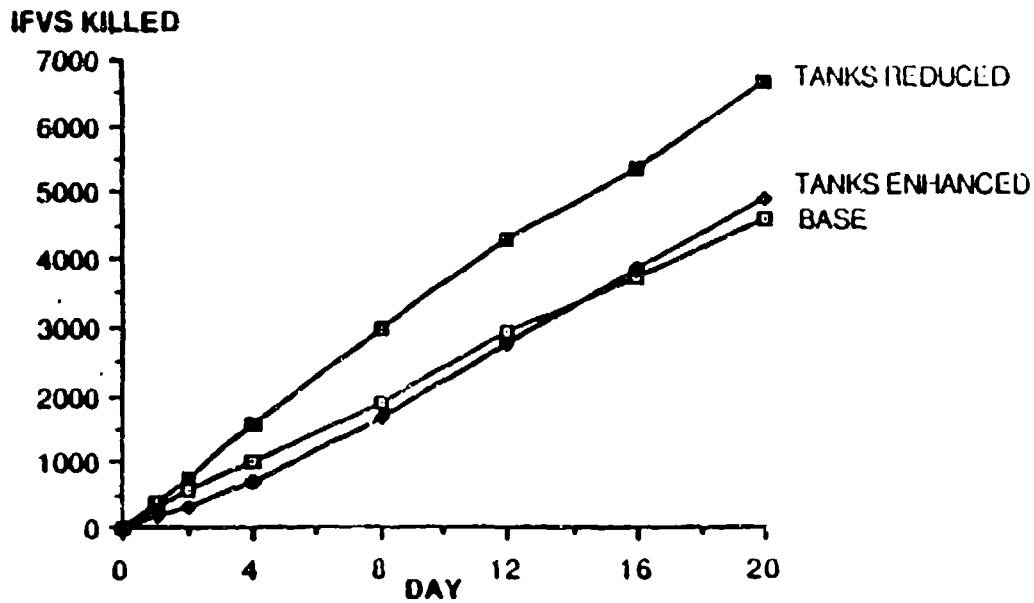


A-4a. Total Tanks Killed NATO

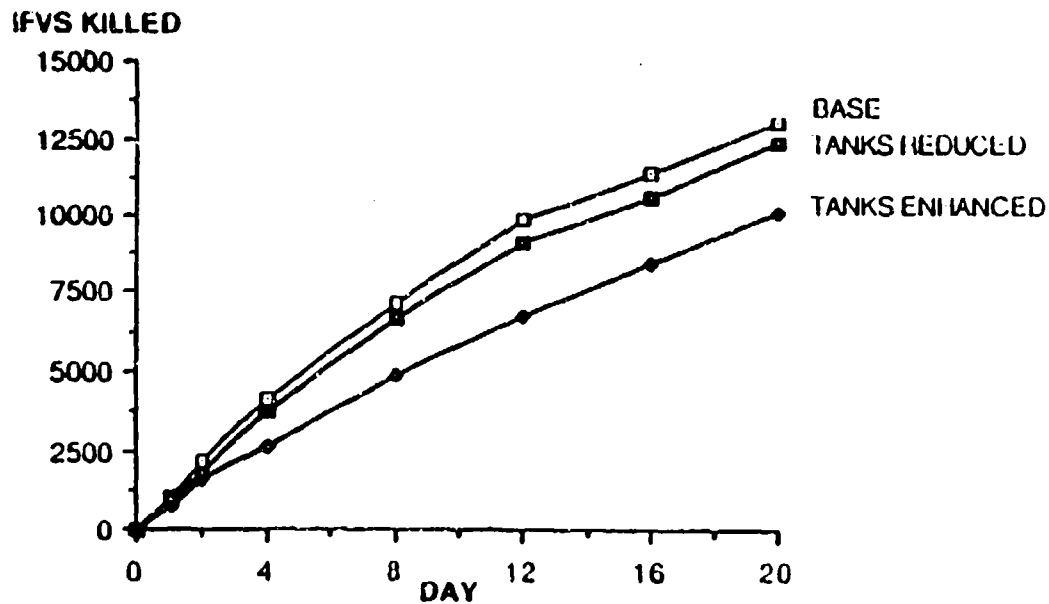


A-4b. Total Tanks Killed Pact

Figure A-4. Effect of Varying NATO Tank Capability



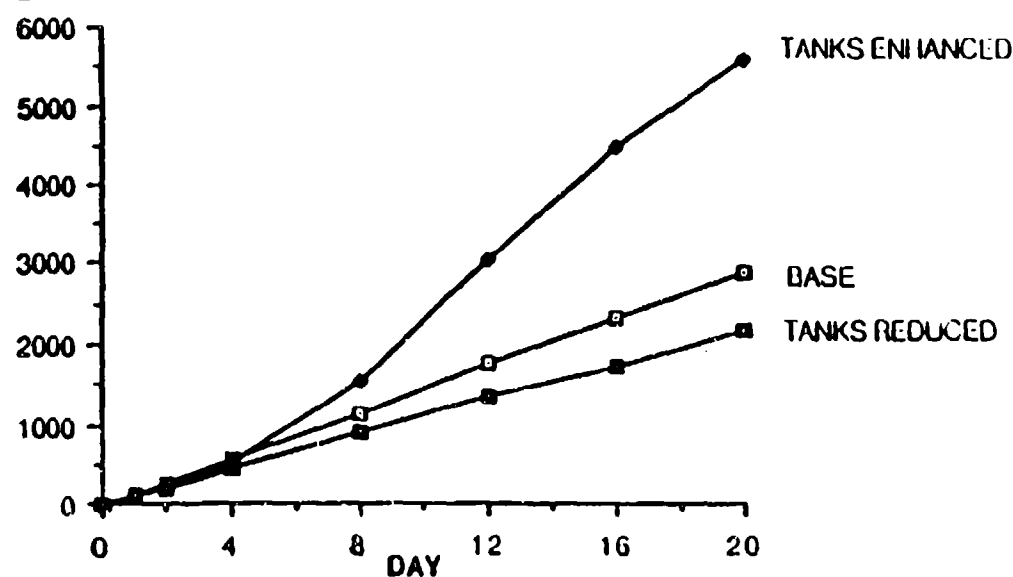
A-4c. Total IFVS Killed NATO



A-4d. Total IFVS Killed Pact

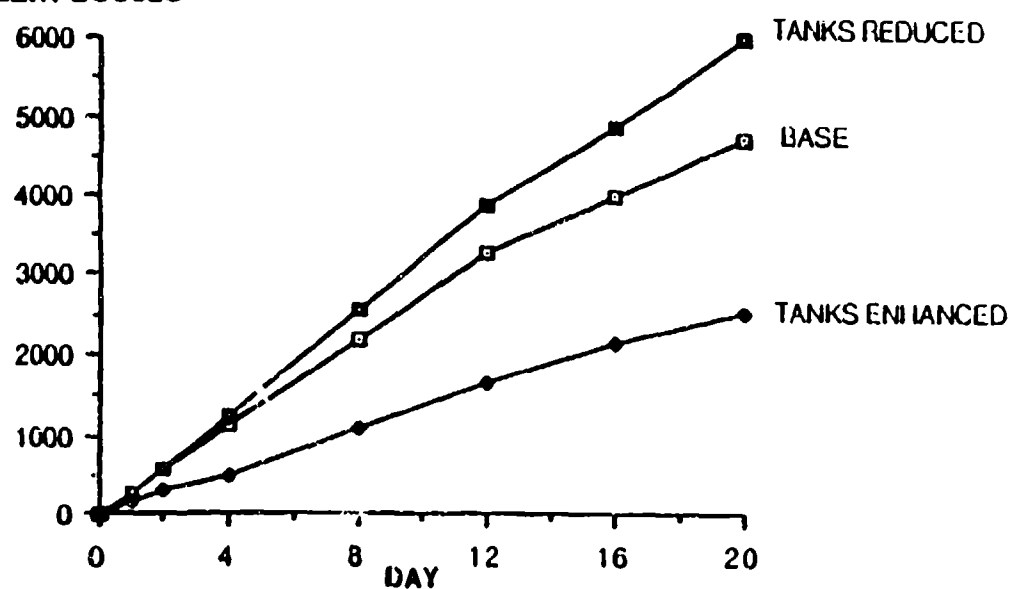
Figure A-4. Effect of Varying NATO Tank Capability (Cont'd)

ARTILLERY LOSSES



A-4e. Total Artillery Killed NATO

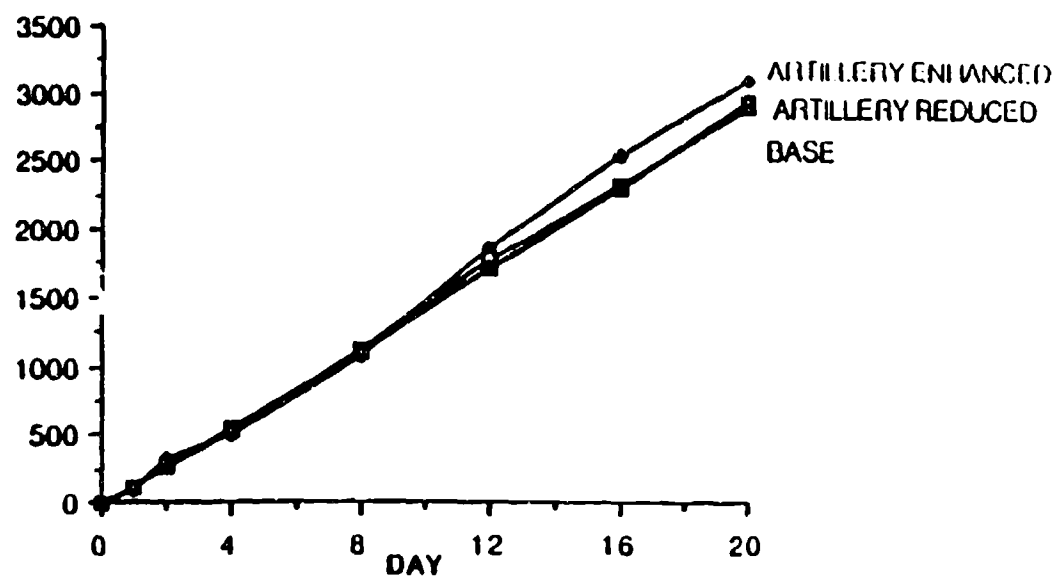
ARTILLERY LOSSES



A-4f. Total Artillery Killed Pact

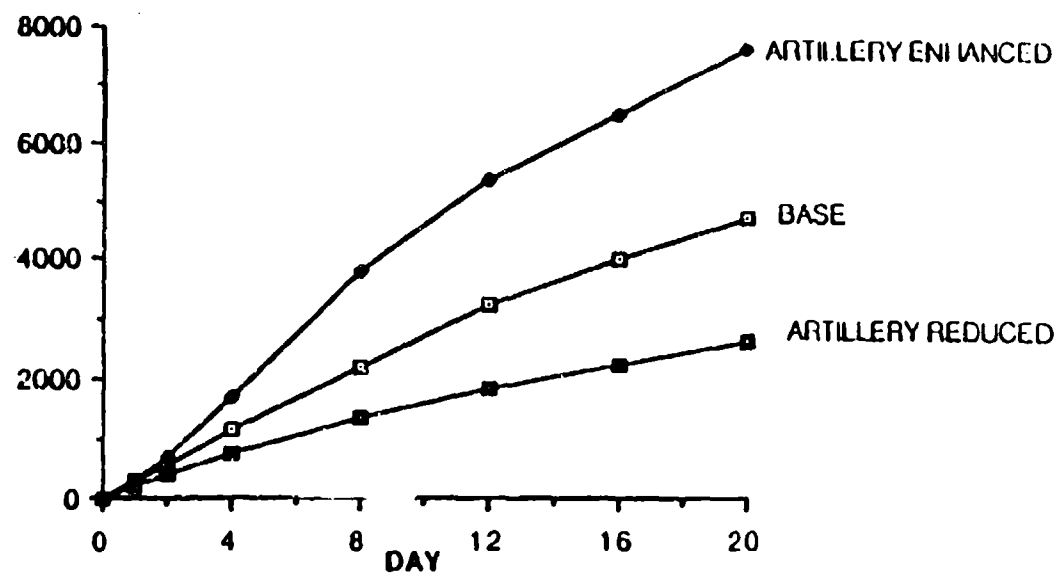
Figure A-4. Effect of Varying NATO Tank Capability (Cont'd)

ARTILLERY LOSSES



A-5a. Total Artillery Killed NATO

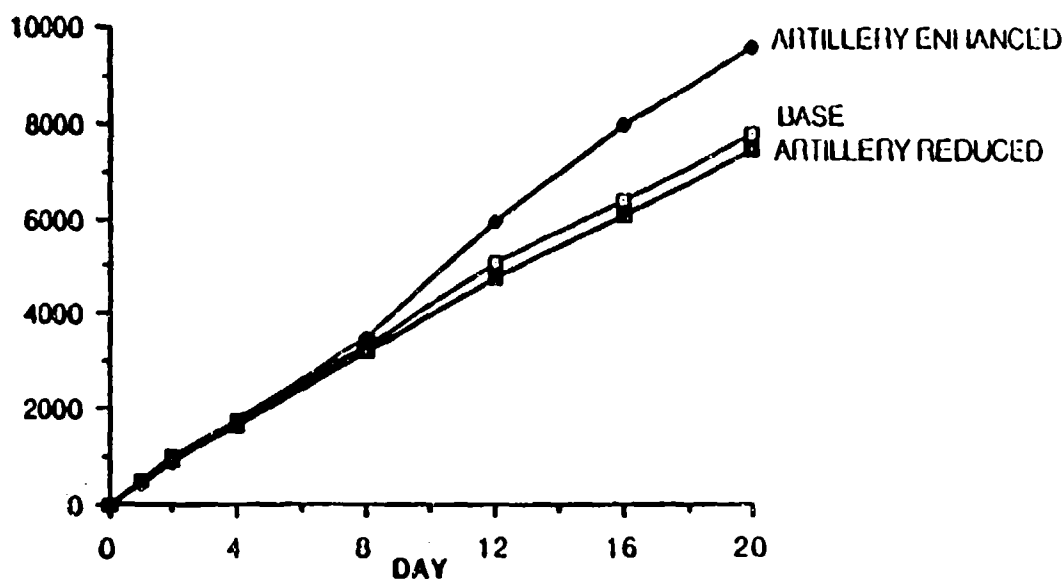
ARTILLERY LOSSES



A-5b. Total Artillery Killed Pact

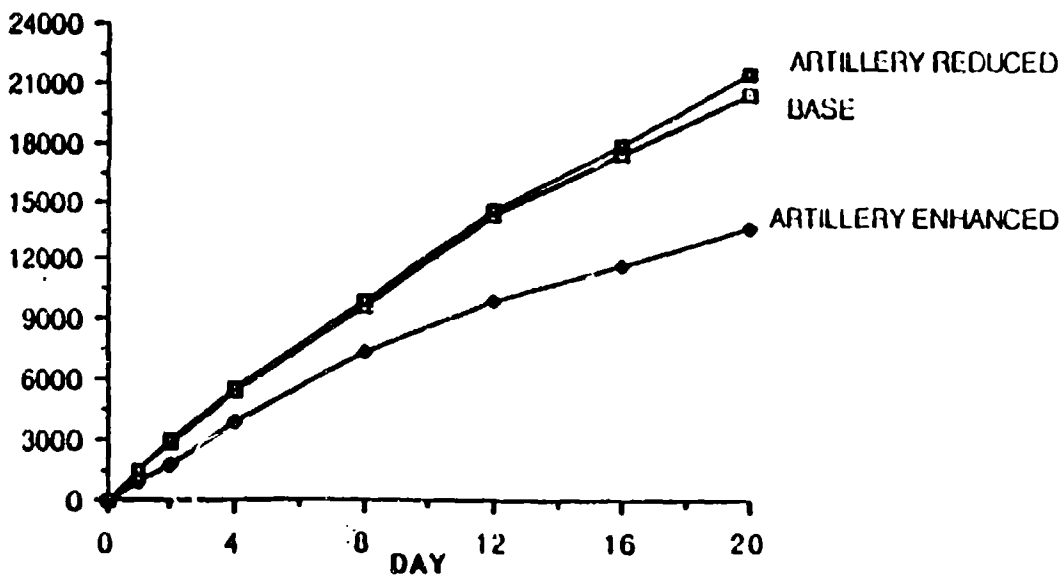
Figure A-5. Effect of Varying NATO Artillery Capability

TANKS KILLED



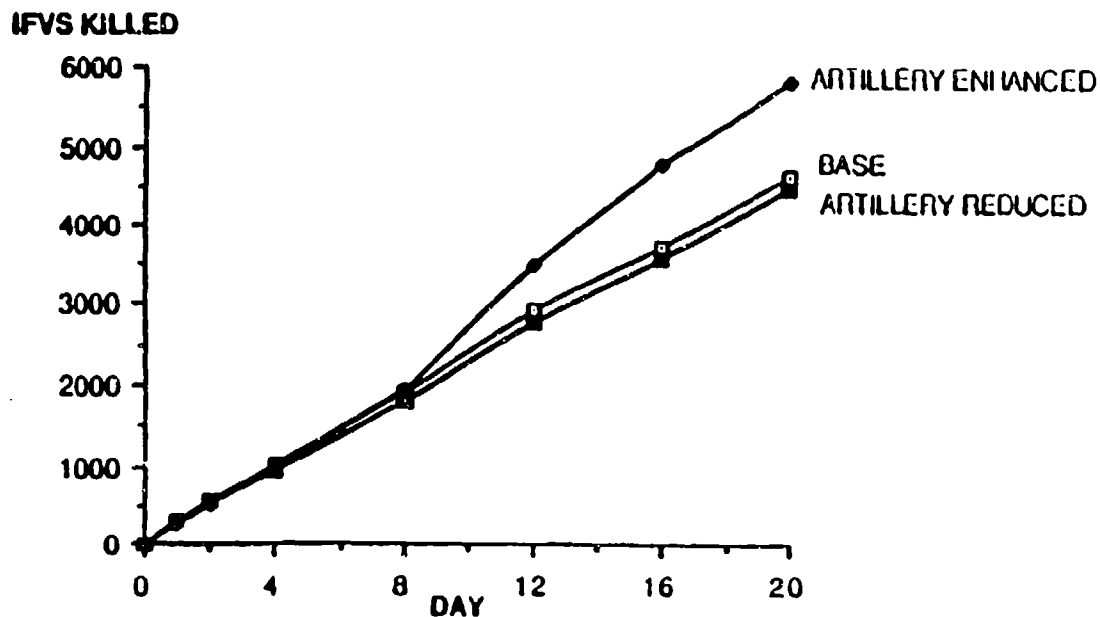
A-5c. Total Tanks Killed NATO

TANKS KILLED

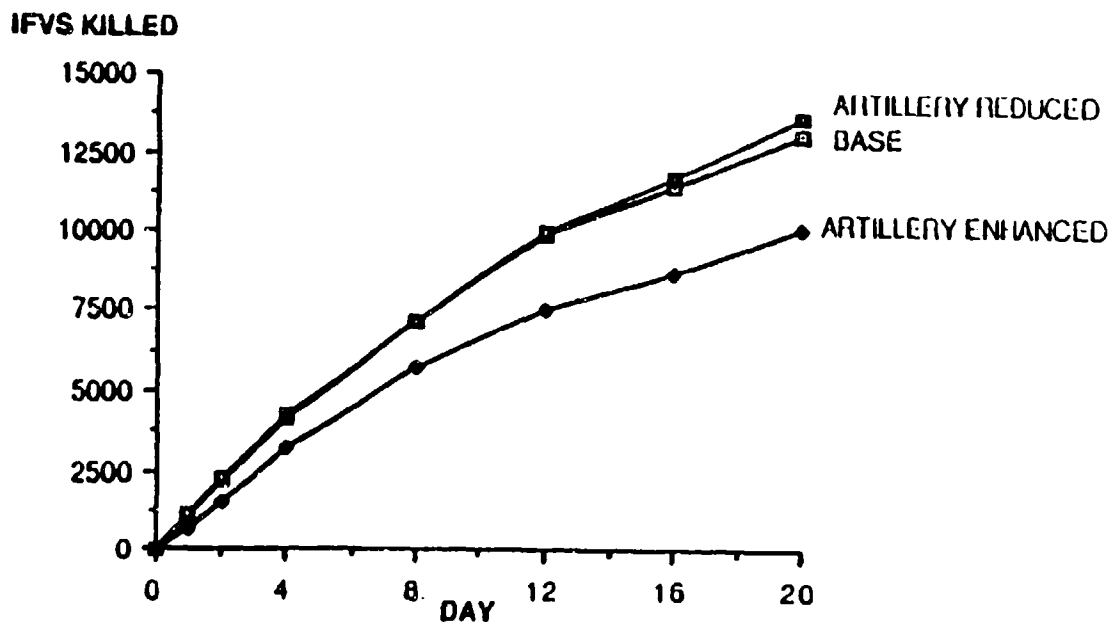


A-5d. Total Tanks Killed Pact

Figure A-5. Effect of Varying NATO Artillery Capability (Cont'd)



A-5e. Total IFVS Killed NATO



A-5f. Total IFVS Killed Pact

Figure A-5. Effect of Varying NATO Artillery Capability (Cont'd)